DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

Bulletin 666

OUR MINERAL SUPPLIES

H. D. McCASKEY AND E. F. BURCHARD
GEOLOGISTS IN CHARGE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1919

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
20 CENTS PER COPY

CONTENTS.

[The letters prefixed to the titles are those used to designate the chapters for advance publication. The dates of publication are given in parentheses.]

	Page.
Introduction by H. D. McCaskey and E. F. Burchard	5
A. Chromite, by J. S. Diller (Apr. 13, 1917)	13
B. Sulphur, by P. S. Smith (Apr. 13, 1917)	19
C. Manganese, by D. F. Hewett (Apr. 18, 1917)	23
D. Platinum, by J. M. Hill (Apr. 18, 1917)	35
E. Gypsum, by R. W. Stone (May 17, 1917)	39
F. Salt, bromine, and calcium chloride, by R. W. Stone (Apr. 30, 1917)	43
G. Sand and gravel, by R. W. Stone (Apr. 30, 1917)	47
H. Asbestos, by J. S. Diller (Apr. 30, 1917)	51
I. Talc and soapstone, by J. S. Diller (Apr. 30, 1917)	55
J. Phosphate rock, by R. W. Stone (May 1, 1917)	57
K. Grinding and polishing materials, by F. J. Katz (May 17, 1917)	61
L. Graphite, by H. G. Ferguson (May 24, 1917)	65
M. Coal, by C. E. Lesher (May 1, 1917)	73
N. Potash, by H. S. Gale (May 9, 1917)	81
O. Bauxite and aluminum, by J. M. Hill (May 28, 1917)	85
P. Alaska's mineral supplies, by A. H. Brooks (June 28, 1917)	89
Q. Copper, by B. S. Butler (Aug. 1, 1917)	103
R. Limestone and lime, by G. F. Loughlin (July 27, 1917)	107
S. Portland cement, by E. F. Burchard (Aug. 10, 1917)	113
T. Clay and clay products, by Jefferson Middleton (June 18, 1917)	119
U. The rarer metals, by F. L. Hess (July 2, 1917)	123
V. Iron, by E. F. Burchard (Aug. 13, 1917)	137
W. Barium and strontium, by J. M. Hill (June 18, 1917)	149
X. Mica, monazite, and lithium minerals, by W. T. Schaller (July 6, 1917)	153
Y. Zinc, by C. E. Siebenthal (July 5, 1917)	159
Z. Nitrates, by H. S. Gale (July 30, 1917)	163
AA. Lead, by C. E. Siebenthal (July 30, 1917)	167
BB. Magnesite, by H. S. Gale (Aug. 20, 1917)	171
CC. Fluorspar, by E. F. Burchard (Oct. 2, 1917)	175
DD. Petroleum, by J. D. Northrop (Sept. 10, 1917)	183
EE. Manganiferous iron ores, by E. C. Harder (Nov. 9, 1917)	197
FF. Quicksilver, by F. L. Ransome (Mar. 20, 1919)	211
GG. Bibliography, compiled under the direction of G. M. Wood (June 30, 1919)	221

ILLUSTRATIONS.

		Page.
PLATE I.	Curves showing principal features of copper industry, 1907–1916	104
FIGURE 1.	Diagram showing the production of Bessemer and open-hearth steel and the combined production and imports of spiegeleisen and ferromanganese, 1901–1915	23
2.	Diagram showing prices of ferromanganese and manganese ore, 1910–1917	29
3.	Domestic production and consumption of Portland cement, 1911–1916	117
4.	Domestic production and consumption of iron ore and pig iron, 1911–1916	143
5.	Domestic production and consumption of fluorspar, 1911–1916	181
6.	Graph showing the total quantity of petroleum marketed annually in the United States from 1859 to 1916 and the total quantity produced annually in all other countries of the world from 1857 to 1916	184

OUR MINERAL SUPPLIES.

INTRODUCTION.

By H. D. McCaskey and E. F. Burchard.

In September, 1914, soon after the beginning of the war in Europe, the Director of the United States Geological Survey summarized the mineral reserves of the United States and made certain suggestions as to making America industrially independent.[1] At that time, two and one-half years before the United States became involved in the war, it was clearly recognized that this country would soon have to face unusual conditions resulting from the depletion or exhaustion of her stocks of imported minerals. Many of these minerals had been imported from choice rather than from necessity, or at least they had been imported when their cost was less than the cost of domestic materials, or because their quality was presumably more desirable, or because their ports of importation were more convenient to the consumers, or for other commercial reasons, and consequently for such minerals it required only the development of an American industry to render our potential supplies available.

In keeping up the supply of minerals that are admittedly lacking or are found in inadequate quantities in the United States a more difficult problem had to be solved. As the war in Europe progressed and ocean commerce became more and more unsettled the difficulty of obtaining supplies of certain minerals increased, and the Geological Survey was called upon by the public and by other Government bureaus for an ever-increasing amount of information and advice concerning these minerals, and also concerning the commercial situation with regard to other more plentiful minerals and their derivatives.

In order to meet this demand with published information a series of papers was prepared by the members of the Survey staff who were most familiar with the minerals required. These papers, collectively entitled "Our mineral supplies," were issued separately in the order

[1] Smith, G. O., Our mineral reserves: U. S. Geol. Survey Bull. 599, 48 pp., 1914.

of their completion. The first one, on chromite, appeared on April 13, 1917, one week after the United States entered the war. All but two of the chapters were available in 1917. The chapter on quicksilver was delayed owing to other demands on the author to whom it was first assigned, although the essential data were given to the war boards informally and served their purpose. In order to complete the series for publication the preparation of this chapter was assigned to Mr. Ransome in September, 1918. The bibliography, compiled under the direction of the Survey editor, affords a convenient check list of the Survey publications on the minerals considered in this volume.

In so far as practicable each chapter contains a discussion of the source of supply of the mineral considered, its uses, both in peace and in war, and the normal demand, and for some of the minerals the probable demand under war conditions is indicated. The table of contents (p. 3) shows the chapters prepared for this bulletin, their authors, and the dates of publication.

The importance of national independence in mineral supplies both in peace and in war needs no demonstration here. In times of peace industrial independence for the United States requires domestic control of such resources as coal, iron ore, and petroleum. Other commodities may in part be imported advantageously because of cheaper sources of foreign supply or superiority of foreign grades, and still others may be almost wholly imported because of lack of known or developed domestic sources of supply. In war times, however, with foreign supplies cut off through hostilities between nations and also by hindrances to commerce, the importance of independence, potential at least, in minerals of all classes becomes most impressive. The lesson that has been pointed out by recent events is that the discovery and development for war purposes of mineral supplies in which the United States is deficient should be undertaken by the Federal Government.

As shown in the several chapters the domestic supplies of minerals may be divided into three classes—(1) mineral supplies that are adequate to all probable peace and war needs of the United States; (2) mineral supplies that are sufficient for a large part of these needs; (3) mineral supplies that are inadequate in quantity or quality, or both, the lack of which must be offset by imports, use of substitutes, or curtailment of use. Among the materials to be grouped in the first class are arsenic, barytes, bauxite, bismuth, bromine, calcium chloride, cement, clay, coal, copper, corundum and emery, diatomaceous earth, feldspar, fluorspar, garnet, gravel, grindstones, gypsum, iron ore, lead, lime, lithium minerals, magnesite, manganiferous ores (low grade), molybdenum, petroleum, phosphate rock, pulpstones, salt, silica, talc and soapstone, sulphur, tripoli, volcanic ash, and zinc; in the second class are antimony, mercury (quicksilver), mica, pyrite, strontium, tungsten, and vanadium; and in the third class are asbestos, chromite, graphite, manganese ore (high grade), monazite, nickel, nitrates, platinum, potash, and tin.

As all the chapters except that on quicksilver were prepared in the spring of 1917, their authors had only the statistics of 1916 available for comparison. Developments during 1917 and 1918 furnish a better indication of the needs of the United States under war conditions than those of earlier years, and inasmuch as the delay in completing the series of chapters permits this introduction to be brought up to a later date a comparison is possible between the quantity of supplies available in a normal pre-war year, such as 1913, and a war year, such as 1917.

The following tables of commodities, by classes 1, 2, and 3 as defined above, show for most of the important commodities in 1913 and 1917 the domestic production, the imports, and the exports, from which may be deduced the approximate quantity available for domestic consumption. The figures for a few commodities are confidential and may not be published.

CLASS 1.—*Domestic mineral supplies adequate to all probable peace and war needs of the United States.*

		Production.	Imports.	Exports.	Quantity available for consumption.
Arsenic [a] (short tons)	1913	2,513	1,519	None.	4,032
	1917	6,151	1,178		7,329
Barytes (short tons)	1913	45,298	35,840	None reported.	81,138
	1917	206,888	6		206,894
Bauxite (long tons)	1913	210,241	21,456	Not separately reported.	....
	1917	568,690	7,691	[b] 21,791	554,590
Bismuth (pounds)	1913	157,300	117,747	None reported.	275,047
	1917	(c)	69,250		....
Bromine (pounds)	1913	572,400	Not specifically shown.	Not specifically shown.	572,400
	1917	895,499			895,499
Calcium chloride (short tons)	1913	19,611			19,611
	1917	30,503			30,503
Cement, hydraulic (barrels of 376 pounds net).	1913	92,949,102	85,470	2,964,358	90,070,214
	1917	93,453,658	2,323	2,586,215	90,869,766
Clay (short tons)	1913	2,647,989	338,123	Not available.	2,986,112
	1917	3,113,844	268,036	83,217	3,298,663
Coal (short tons)	1913	569,960,219	1,612,550	[d] 24,798,080	546,774,689
	1917	651,402,374	1,460,983	[d] 29,846,863	623,016,494
Copper, new (refined) (pounds)	1913	1,236,823,913	378,243,869	[e] 817,911,424	797,156,358
	1917	1,873,546,171	555,000,000	[f] 1,126,875,368	1,301,670,803
Emery and corundum (short tons)	1913	[g] 957	[h] 20,426	Values only recorded.	....
	1917	17,135	[h] 2,287		....
Feldspar (short tons)	1913	120,955	Not specifically shown.	Not specifically shown.	....
	1917	141,924			....
Fluorspar (short tons)	1913	115,580	22,682	None reported.	138,262
	1917	218,828	13,616		232,444
Garnet, abrasive (short tons)	1913	5,308	Not reported separately.	Not reported separately.	....
	1917	4,995			....
Gravel (short tons)	1913	40,861,694	Values only recorded.	Values only recorded.	....
	1917	35,573,819			....
Grindstones and pulpstones (short tons).	1913	Values only.	[i] 7,726	Values only recorded.	....
	1917	[j] 54,432	[i] 3,012		....
Gypsum, crude (short tons)	1913	2,599,508	447,383	Not recorded.	....
	1917	2,696,226	240,269		....
Iron ore (long tons)	1913	61,980,437	2,594,770	1,042,151	63,533,056
	1917	75,288,851	971,663	1,132,313	75,128,201
Lead, refined (short tons)	1913	411,878	11,980	None.	423,858
	1917	548,450	6,887	56,209	499,128
Lime (short tons)	1913	3,595,390	4,139	29,475	3,570,054
	1917	3,786,364	7,353	18,794	3,774,923
Lithium minerals (short tons)	1913	530	Not reported separately.	Not reported. separately.	....
	1917	2,062			....
Magnesite, crude (short tons)	1913	9,632	13,240	Not recorded, negligible.	22,872
	1917	316,838	30,277	Not recorded.	347,115
Manganiferous ore [k] (long tons)	1913	59,403	Included under iron ore.	None.	59,403
	1917	860,944			860,944
Molybdenum (pounds)	1913	None.	156,000	None recorded.	156,000
	1917	350,200	None recorded.		350,200
Petroleum (barrels of 42 gallons)	1913	248,446,230	17,809,058	[l] 4,630,229	261,625,059
	1917	335,315,601	30,162,583	[l] 4,098,124	361,380,060
Phosphate rock (long tons)	1913	3,152,208	Negligible.	1,366,508	1,785,700
	1917	2,851,886		166,358	2,685,528
Salt (short tons)	1913	4,815,902	154,765	70,289	4,900,378
	1917	6,978,177	64,922	113,993	6,929,106
Silica (short tons)	1913	204,759	None reported.	None reported.	204,759
	1917	675,127			675,127
Sulphur (long tons)	1913	491,080	22,605	89,221	424,464
	1917	1,134,412	1,015	152,833	982,594
Talc and soapstone:					
Talc (short tons)	1913	149,271	13,770	None reported.	163,041
	1917	198,613	18,609		217,222
Soapstone (short tons)	1913	26,562	Not separately reported.	Not separately reported.	....
	1917	20,235			....
Tripoli and diatomaceous earth [m] (short tons).	1913	27,383	Values only.	Not recorded.	....
	1917	29,102			....
Zinc (short tons)	1913	337,252	[n] 19,597	7,783	349,066
	1917	584,597	[n] 72,731	153,796	503,532

[a] White arsenic, As_2O_3.
[b] Includes bauxite concentrates.
[c] Only two producers and Survey not at liberty to publish figures.
[d] Exclusive of bunker coal.
[e] Exclusive of manufactured copper, as pipes and tubes, plates and sheets, and wire.
[f] Exports of pigs, ingots, bars, rods, pipes, and tubes, plates and sheets, and wire.
[g] Emery only. No corundum produced.
[h] Grains, ore, and rock.
[i] Represents grindstones only.
[j] Quantity represents grindstones only, as pulpstones were not reported by weight.
[k] Containing 5 to 35 per cent of manganese.
[l] Exports of refined products are not included nor are shipments of crude petroleum to Alaska, Hawaii, Porto Rico, and the Philippine Islands.
[m] Includes rottenstone, but excludes, in 1917, considerable production of diatomaceous earth for special uses upon which the Survey is not at liberty to report.
[n] Zinc content of ore plus blocks or pigs.

CLASS 2.—*Domestic mineral supplies sufficient for a large part of peace and war needs of the United States.*

		Production.	Imports.	Exports.	Quantity available for consumption.
Antimony (short tons)	1913	Not recorded.	a 8,250	None.	....
	1917	258	a 17,914	None.	18,172
Mica (short tons)	1913	6,172	Quantity not reported.	149	....
	1917	4,067		b 6	....
Pyrites (long tons)	1913	341,338	c 850,592	None reported.	1,191,930
	1917	462,662	c 967,340		1,430,002
Quicksilver (flasks of 75 pounds)	1913	20,213	2,289	1,140	21,362
	1917	36,159	5,207	10,778	30,588
Strontium ore (short tons)	1913	No record.	No record.	None reported.	....
	1917	4,035	d 1,700		5,735
Tungsten e (short tons)	1913	1,537	2,114	....	....
	1917	6,144	4,878	2,420	8,602
Vanadium (short tons)	1913	432	None reported.	None reported.	432
	1917	484			484

a Antimony content of ore plus metallic antimony, and antimony sulphide.
b For six months, January to June. Not separately classified after June.
c Pyrites containing more than 25 per cent of sulphur.
d Imports of English celestite.
e These figures represent ore carrying 60 per cent tungsten trioxide.

CLASS 3.—*Domestic mineral supplies chiefly inadequate in quantity or quality, or both for peace and war needs of United States.*

		Production.	Imports.	Exports.	Quantity available for consumption.
Asbestos (short tons)	1913	1,100	97,145	Not separately recorded.	....
	1917	1,683	134,108	708	135,083
Chromite (long tons)	1913	255	65,180	None.	65,435
	1917	43,725	72,063	None.	115,788
Graphite a (short tons)	1913	4,775	28,879	2,692	30,962
	1917	13,593	42,577	2,573	53,597
Manganese ore b (long tons)	1913	4,048	345,090	....	349,138
	1917	129,405	629,972	....	759,377
Monazite sand (pounds)	1913	None.	817,810	None reported.	817,810
	1917	(c)	5,828,270		....
Nickel (short tons)	1913	d 241	e 23,723	f 14,587	9,377
	1917	d 402	e 37,763	f 10,996	27,169
Nitrates, sodium and potassium (short tons)	1913	None.	691,230	....	691,230
	1917	None.	1,732,996	....	1,732,996
Platinum (troy ounces)	1913	g 1,034	h 118,661	Not separately recorded values only.	....
	1917	g 7,384	h 30,207		
Potash salts i (short tons)	1913	....	k 1,092,588	....	n 1,092,588
	1917	j 126,961	l 25,287	m 525	n 151,723
Tin, metallic (short tons)	1913	50	52,329	Insignificant and not recorded.	52,379
	1917	110	72,166		72,276

a Unmanufactured graphite.
b Containing 35 per cent or more of manganese.
c Only one producer and Survey not at liberty to publish figures.
d Nickel content of nickel salts and metallic nickel produced as a by-product in the electrolytic refining of copper.
e Nickel, nickel ore and matte, nickel oxide, alloys of nickel with copper, etc., imported for consumption.
f Nickel and nickel oxide.
g Refined new metals of the platinum group of domestic origin.
h Ore, unmanufactured, ingots, bars, sheets, wire.
i Gross weight.
j Available potash (K_2O), 32,573 short tons.
k Potash (K_2O) content, 270,720 short tons.
l Potash (K_2O) content, 8,100 short tons.
m Domestic potash salts, potash (K_2O) content, 200 short tons.
n Potash (K_2O) content: 1913, 270,720 short tons; 1917, 40,473 short tons.

The reaction of the war upon the demand for the several commodities is of interest. In abrasives, chemical materials, fertilizers, fuels, metals, and refractories, with few exceptions, domestic production was greater in 1917 than in 1913, whereas the output of structural materials was generally less. The classes of materials whose domestic production increased were all directly or indirectly contributory to the conduct of the war; the civil consumption of certain materials was less than normal because of governmental restrictions in use and because of high prices, but the military uses more than made up the deficiency. Inspection of the table shows also that of a few commodities the quantity available for consumption in 1917 was less than in 1913 on account of curtailment of imports, notwithstanding considerable increases in domestic production.

In any consideration of mineral supplies the actual consumption is all-important. The last column of each table shows the quantities available for consumption as calculated by adding production and imports and subtracting exports. These quantities may be very different, especially in war times, from the quantities actually consumed, because stocks accumulated in a former year may be heavily drawn upon. More complete data on stocks and on actual consumption of materials, even in peace times, are needed. As estimates of military needs alone and of shipping available have varied greatly and have been revised from time to time during the war, it is evident that consumption must vary, and a consideration of all factors shows that circumstances may at any time lead to the transfer of mineral commodities from one classification to another. For example, data originally made available to the war boards by consumers, combined with other data at hand, indicated at one time a serious shortage in supplies of chromite. Production was encouraged, imports were permitted to a certain extent, and conservation in consumption of the chromite available was attained, but these measures combined led to an actual oversupply and corresponding distress to the producers who were operating under war-time costs and who failed, at least in part, to receive the expected corresponding war-time prices.

Similarly, quality is often a factor as important as quantity in reckoning our independence of foreign supplies. For example, it was found necessary to import certain quantities of graphite, mica, asbestos, and several other minerals because for some uses the quality of the domestic material, no matter what the quantity, was not adapted to particular needs, whether of war or of peace.

On the whole, the severe test of war has shown that the United States possesses a larger degree of independence in mineral supplies than any other nation, especially in times when cost of production has been relegated to the rear. In peace times cost is of course a determining factor, and a number of mineral industries that have thrived under war conditions are already declining under the pinch of foreign competition and decreased demand.

It is to be regretted that data on consumption and on cost of production have never been available in any Government organization in such completeness as the data on production compiled in the Geological Survey and the data on imports and exports compiled in the Bureau of Foreign and Domestic Commerce. It is to be hoped that means may be found to remedy these deficiencies and to improve related data already provided for, in order that more exact knowledge may be available for better preparedness in the future.

The cost of the war has been great, in blood and in treasure. The tuition fees that must be paid for the lessons that have been taught by national unpreparedness are so heavy that they must be borne in part by future generations. It will be unfortunate indeed if these lessons are not fully learned and applied in practice.

CHROMITE.

By J. S. Diller.

The importance of chromite as a war supply in the manufacture of armor plate, armor-piercing projectiles, stellite for high-speed tools, and automobile and other special steels can scarcely be overestimated. Fortunately for users of chromite the foreign deposits, which at the beginning of the European war were the chief source of the world's supply, are not wholly within the war arena, so that production of chromite has not only continued but has expanded without interruption to meet the demands superimposed by the war. The chief sources of supply for the United States during the last few years have been Rhodesia, New Caledonia, Turkey, and Greece.

Embargoes were placed on the shipment of chrome ore from some of the principal sources, and it was feared by some that the supply for the United States would be cut off, but after the producers received a guaranty that the ore would not be reshipped to enemy belligerents the imports, as shown in the following table, greatly increased, especially those from Rhodesia, New Caledonia, and Canada, though those from Greece have declined slightly and those from Turkey have entirely ceased.

Chromic iron imported into the United States, 1913–1916, in long tons.[a]

	1913	1914	1915	1916
Cuba	....	....	....	34
Canada	....	533	10,087	10,930
England	....	58	2	5
Greece	....	8,155	4,305	7,900
Japan	322	....	....	....
French Oceania	6,620	30,860	28,031	[b] 30,950
Australia	....	....	....	[b] 2,986
British South Africa	....	....	22,800	[c] 23,000
Portuguese Africa	29,000	23,200	11,230	[c] 38,850
Turkey in Asia	13,830	11,880	....	....
	49,772	74,686	76,455	114,655

[a] Statistics furnished by the Department of Commerce, Bureau of Foreign and Domestic Commerce.
[b] E. J. Lavino & Co., importers, credit New Caledonia with all that listed above under French Oceania and Australia, amounting to 33,936 long tons.
[c] E. J. Lavino & Co., importers, credit Rhodesia with all that listed above under British South Africa and Portuguese Africa, amounting to 61,850 long tons.

Chromic iron produced and sold in the United States, 1913–1916, in long tons.

	1913	1914	1915	1916
United States	255	591	3,281	[a] 40,000

[a] The preliminary estimate was 35,000 long tons, but later information indicates that the total amount sold was not less than 40,000 long tons. A considerable amount of ore mined but not yet sold is not included in this estimate.

The greatly increased trade, especially in steel, and the consequently larger demand for chromite have stimulated the search for it in the United States, as shown by the tenfold increase in production. On the Atlantic coast and in Wyoming there has been only a small production, but in the Pacific Coast States, especially California, the advance in the output has been remarkable. Maryland and Wyoming, with one producer in each State, made with Oregon an aggregate output of more than 3,000 long tons in 1916; in California the production was not less than 40,000 tons.

It is evident that for some time to come California will furnish the chief domestic supply. With a lively demand and good prices bodies of ore farther from lines of transportation will be worked. The production from some deposits in 1917 is expected to exceed that of 1916, but that the total output of the State will be increased is not certain. It is possible, however, that some counties—Del Norte, for instance—which produced no chromite in 1916, will produce much in 1917 on account of better transportation facilities, both by land and sea.

There were two main belts of production in California—one in the Klamath Mountains and Coast Range from Siskiyou County to San Luis Obispo County and the other in the Sierra Nevada from Plumas County to Tulare County. The larger output has come from the Klamath Mountains, because the ore bodies there are larger and railroad transportation is more convenient, features which will continue to make it for years an important producing region.

The production in Oregon is increasing in both the Klamath and Blue mountains. The ores west of Riddle are the richest yet mined in the State; in some places they run as high as 55 per cent chromic oxide, and much of the ore contains about 50 per cent. Most of the Oregon ore, however, like that of California, averages about 40 per cent of chromic oxide, and ore of that grade is commonly the basis of sale. The ore generally contains 38 to 45 per cent chromic oxide, 6 to 8 per cent silica, and 17 to 25 per cent alumina.

The largest ore body and producing mine thus far developed in Oregon is owned and operated by Collard & Moore near Holland, about 20 miles southeast of Kerby, in Josephine County. Much of the ore may be improved by concentration, and a plant of 90-ton capacity for that purpose is nearly completed. It is claimed that the ore can be concentrated to a content of 55 per cent chromic oxide. If this can be done successfully, it will mean much for the chrome industry of the Pacific coast and will enlarge its possibilities to meet war demands. The difficulty with much of the chrome ore of the Pacific coast has been its low grade and its great distance from the principal markets. The low-grade ore, running 38 to 45 per cent chromic oxide, may be used to advantage chiefly for metallurgic purposes, such as grow out of war demands—for furnace lining and in the manufacture of chrome brick and chrome steel, for example—and by far the greater part of the California output is being so used. For chemical purposes, however, ore of higher grades is desirable, if not essential. The concentration of the ore would give it a wider market and increase its value and the demand for it. Without concentration the Pacific coast deposits can not furnish a dependable supply of high-grade chrome ore, but with successful concentration industries based on high-grade ore may be attracted to the coast. The Sawyer Tanning Co., whose plant was recently established on tidewater at Napa, Cal., has had great difficulty in obtaining sufficient high-grade ore for its own use.

T. W. Gruetter has recently established at Kerby, Oreg., a custom plant for concentrating black sand to win its gold and platinum. The black sand of the Klamath Mountains usually contains a considerable amount of chromite, and it is believed that by adding magnetic separators to Gruetter's plant to remove the other minerals from the tailings sufficient chromite may be obtained from the black sand in chromiferous serpentine areas to make the operation financially successful. The process will evidently yield a high grade of chrome ore, which may be suitable for special uses.

The relation of these experiments in concentration to the whole problem of obtaining high-grade chrome ore on the Pacific coast will be better understood when attention is called to the fact that by the disintegration and washing away of the weathered serpentine (an intrusive igneous rock in which practically all the chromite deposits occur) the heavy grains of chromite are left behind, and, consequently, the soil or surface wash in the watercourses of serpentine areas becomes enriched by the accumulation of residual chromite. Chromite boulders and sand are therefore, as a rule, more abundant in the surface soil than in the solid serpentine beneath. Many prospectors who find boulders of chromite on the surface feel confident that there is a large body of chromite beneath, but a few shallow prospect holes usually prove that the occurrence consists simply of surface soil enriched by residual chromite, and disappointment results.

The prices of chromite in California on the basis of 40 per cent chromic oxide ranged in 1916 from $14 a ton f. o. b. early in the season to $20 toward the end of the year. To this must be added for the eastern buyer a freight rate for carload lots ranging from $10 a ton to Chicago to $14.86 a ton to the eastern seaboard, thus making the California 40 per cent ore cost on the eastern seaboard from $28.86 to $34.96 a ton.

Chromite is now being produced in eastern Oregon and also in Inyo County, Cal., at points east of the Pacific mountain belt and nearer the consumer than those in the mountains near the coast. The output from these two localities may ultimately prove to be large, and the shortening of the haul would materially reduce the cost of transportation.

The long haul across the continent is one of the chief difficulties in supplying the western chromite to the consumer, and this difficulty would be augmented in time of war by the other demands of transcontinental traffic. If, however, a greater production could be developed on the eastern slope of the Rocky Mountains, as near Glenrock, Wyo., where railroads are more numerous and transportation available on lines that are not transcontinental, the war supply of chromite would be more conveniently enlarged. There is good reason to believe that the serpentine of the Laramie and Big Horn mountains may contain considerable bodies of chromite.

In the Atlantic States, where most of the chromite produced in this country is used, the only production is in the vicinity of Baltimore, where the chrome industry of the United States was started by the Tysons many years ago. At first bodies of chromite were quarried from the serpentine areas about Baltimore and northeastward into Pennsylvania, but as the supply of known ore bodies became exhausted the chromiferous residual deposits of the soil and the stream gravel of the small valleys within the serpentine areas were washed for chrome sand. A small output of chrome sand is now obtained at Soldiers Delight, near Baltimore. The washing is done during low water in summer by means of a sort of sluice box locally called a "buddle." The sand is commonly passed through the buddle five times to reach the desired concentration, when it may contain as much as 55 per cent chromic oxide. Formerly the product was all exported for use in manufacturing special colors, but lately some of it has been used in the United States in making chrome steel, and the demand for it is increasing. This enterprise suggests the possibility of considerable expansion in the utilization of chromite sand in Maryland and Pennsylvania.

The only other Atlantic Coast State in which there are known deposits of chromite that may be workable is North Carolina. The deposits occur in five counties in the western part of the State and are described by Pratt and Lewis.[1] No large deposits of chromite

[1] Pratt, J. H., and Lewis, J. V., Corundum and the peridotites of western North Carolina: North Carolina Geol. Survey, vol. 1, 1905.

have yet been found in North Carolina, but the prospects already opened show that extensive deposits may exist in that region. Railroads traverse Yancey County, where chromite deposits should be diligently sought.

There is considerable chromite in Cuba, but scarcely anything is known of its occurrence in Mexico or Central and South America.

Ferrochrome, the alloy used in making chrome steel, is now manufactured in the United States by electro-metallurgic methods, almost wholly in the East, at the plants of the Electro Metallurgical Co. at Niagara Falls and elsewhere. It is reported, however, that the Noble Electric Steel Co. has three furnaces at Heroult, Cal., operating to their full capacity in producing manganese, chrome, and silica steels.

Prospecting for chromite may disclose other supplies, and the most profitable deposits will be those in serpentine areas that are adjacent to cheap rail or water transportation or connected with it by good roads. Cheap concentration may in places improve the grade of the ore available for profitable mining.

With the known supplies of chromite and others whose discovery within the limit of practicable transportation throughout the United States is confidently expected, there is good reason to believe that the domestic output of chromite could be so increased as to go far toward supplying the demand if in the event of war our imports, except those from Canada, were cut off.

Vogt and others have made extensive researches concerning the genesis of chromite. The distinction between primary and secondary ores and their relation to geotectonic features that determine the distribution of chromite in the field are geologic problems of great importance.

The metallurgy of chromite has apparently been so developed in the hydro-electric process as to utilize to advantage relatively low-grade ores such as are most abundant in the United States, and the further development of that process on the Pacific coast, where water power abounds, would greatly diminish the handicap of long transportation.

127972°—19——2

SULPHUR.

By Philip S. Smith.

Practically every industry requires the use of sulphur in some form, and the United States, to be industrially independent, must therefore have an adequate supply. That this country has enough sulphur to support its present industries, even under the requirements imposed by the drain of a vast foreign demand, seems to have been demonstrated by the record of the last three years.

The two main sources of the element sulphur are the native mineral and the sulphides. Each year at least 300,000 long tons of native sulphur and $1,250,000 long tons of sulphides are used, mostly for the manufacture of sulphuric acid. In 1916 about 25 companies were producing sulphur and about 100 companies were mining sulphides mainly for their sulphur content.

NATIVE SULPHUR.

More than 98 per cent of the native sulphur produced in the United States at this time comes from deposits in Louisiana and Texas, but deposits that have been or might be productive are known in Wyoming, Nevada, Utah, California, Colorado, Oregon, and Alaska.

Louisiana and Texas apparently produce enough sulphur to supply even an extraordinary demand, for the combined output of these two States, although the production has not been vigorously pushed, has so greatly exceeded the amount sold that large stocks of sulphur have been accumulated. Even under the conditions that now prevail this country exports much more sulphur than it imports. The excess in 1916 amounted, in round figures, to 107,000 long tons, valued at $2,100,000; in 1915 to 11,000 tons, valued at $250,000; in 1914 to 72,000 tons, valued at $1,300,000; and in 1913 to 66,000 tons, valued at $1,100,000. The great falling off of exports in 1915 may have been due in part to the increased use of sulphur in industries in this country. In part, however, probably in large part, the decrease was due to the difficulties and dangers of transportation to foreign ports. At first sight this explanation does not seem to be borne out by statistics regarding imports of either sulphur or pyrite, for the quantities imported in 1913, 1914, and 1915 show no appreciable change. This comparison, however, is not pertinent, for whereas practically all the sulphur and pyrite imported by the United States comes from and passes through regions that are comparatively peaceful, most of the sulphur exported by the United States goes to or through regions now in the midst of war. That the falling off of exports in 1915 was due to a cause other than dearth of raw material in the United States is clearly shown by the record for 1916.

Large reserves of sulphur have already been accumulated, so that considerable increase in demand could be supplied for some time by drawing against these reserves even if only a normal production was maintained. Without these reserves and easily worked deposits this country would have extreme difficulty in supplying enough sulphur to meet its most urgent normal needs. As a preparedness measure, therefore, the other deposits that are now idle should be thoroughly developed, search should be made for new deposits in areas where the geologic conditions are similar to those in the vicinity of the known deposits, and the deposits of sulphide ores should be intensively developed.

SULPHIDES.

The United States in 1913 produced about 350,000 long tons of pyrite and imported about 850,000 tons. If these figures represent the normal condition of the industry, it is evident that ordinarily the United States uses each year about 850,000 tons more pyrite than it produces. The imported pyritic ore has an average sulphur content of approximately 45 per cent, so that 380,000 tons of native sulphur would be required to make up this deficiency if the importation of pyrite were cut off. In 1916 we exported 107,000 tons of sulphur more than we imported. If the exportation of sulphur were prohibited, as it doubtless would be if imports of sulphides were cut off, this excess amount would therefore be available and at the 1916 rate would make up nearly one-third of the deficiency that would be created by the shutting out of imported pyrite. The deficiency could be reduced still more by drawing on the reserves of sulphur already mentioned, but doubtless it would be far better not to use the high-grade native sulphur for many of the purposes for which pyrite may be used, but rather to save more of the sulphur from the sulphide ores and to hunt for and develop additional deposits of sulphides.

Scores if not hundreds of deposits of sulphides situated in many States in the Union are mined. Most of these deposits owe their main value at the present time to their content of gold, copper, zinc, or metals other than sulphur. At most of the smelters that treat these ores the sulphur is neglected and allowed to escape, thus not only causing a direct loss but in some localities ruining the adjacent country by the fumes, which are highly injurious to vegetation. Processes for the recovery of the sulphur from these gases have been so perfected that even under normal conditions they will ordinarily pay well for their installation, and when a national demand for sulphur arises their adoption will become imperative. By this means a large volume of sulphur now worse than wasted would be made available.

With a greater demand for the metals doubtless most of these deposits would be much more actively mined for their copper, lead, or zinc content, so that the treatment of the ores would furnish an increasing amount of fumes available for sulphur recovery. Under these circumstances a considerable volume of sulphur would be produced and could make up a large share of the deficiency caused by cutting off the importation of sulphides.

If these two measures, however, still did not provide enough sulphur, recourse should be had to the opening and development of many of the now inactive sulphide deposits that are widely distributed throughout the country. Little doubt is felt that if cost should cease to be the controlling factor, or if prices should sufficiently advance, an adequate supply of sulphur from these sulphides could be obtained. Moreover, if the metallurgic problems connected with the recovery of sulphur from low-grade ores of mixed sulphides were successfully solved, many deposits of sulphides now unsuitable for commercial purposes could be developed, and therefore inventive genius should be directed at once toward this end.

SULPHURIC ACID.

According to preliminary estimates the United States in 1916 produced about 4,500,000 tons of sulphuric acid of a strength of 50° Baumé and nearly 1,000,000 tons of acid of strength higher than 66° Baumé. This amount exceeds the amount of similar acids produced in 1913 by more than 950,000 tons of 50° Baumé acid and by more than 900,000 tons of acid of strengths higher than 66° Baumé.

Almost no sulphuric acid is imported into the United States, and but a relatively small amount is exported, even under the conditions now prevailing. The reports of the Bureau of Foreign and Domestic Commerce show that in 1916 a little over 600 tons of acid was imported and about 33,000 tons was exported.

Sulphuric acid for the production of munitions of war, for refining petroleum derivatives, and for the manufacture of superphosphates and artificial manures for use in agriculture is required in increasing quantities. Means for augmenting the supply of part of the raw material for these purposes have already been discussed, but other resources must be available before a greatly increased amount of acid can be produced. It is important to realize that ordinary concentration plants for making acid of the strongest grades from weaker acid can be built in a relatively short time, but it will take much longer to build plants designed for the production of the acid itself.

About 200 plants, widely distributed throughout the United States, are now engaged in the manufacture of sulphuric acid. Most of these plants are in the neighborhood of the larger cities, and many of those in the East are on navigable waterways, as well as on railroads.

MANGANESE.

By D. F. Hewett.

INTRODUCTION.

Manganese is an essential element in the steel industry. Prior to 1870 the iron used was largely in the form of cast and wrought iron and crucible steel, to which no manganese is added. The develop-

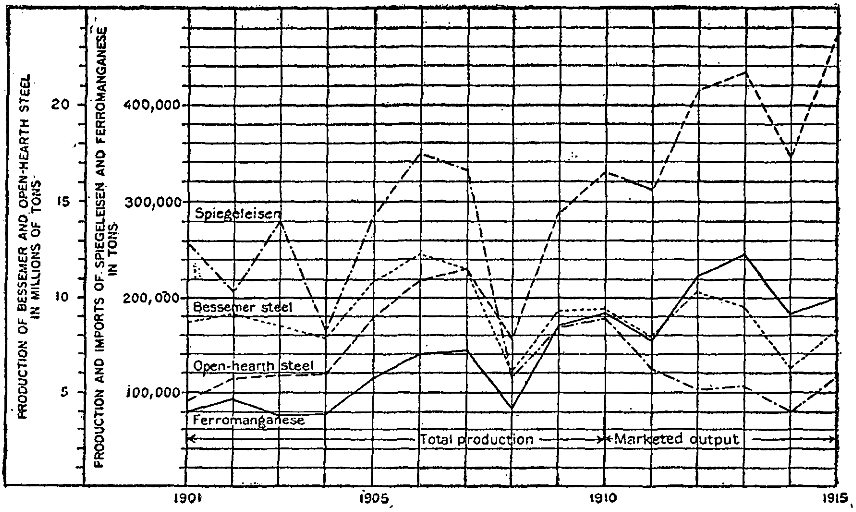


FIGURE 1.—Diagram showing the production of Bessemer and open-hearth stee and the combined production and imports of spiegeleisen and ferromanganese, 1901-1915.

ment of the Bessemer and open-hearth processes of making steel about 1870 created a demand for manganese alloys, and during recent years about 14 pounds of manganese in the form of ferromanganese or spiegeleisen is added to every ton of steel produced by these processes. Ferromanganese contains from 77 to 80 per cent of manganese and is largely used in making open-hearth steel. Spiegeleisen contains 12 to 33 per cent of manganese and is largely used in making Bessemer steel. Manganese also forms a large part of certain alloys that are almost essential to modern industry and are used especially in the manufacture of grinding and crushing machinery.

In addition, certain grades of manganese ore are needed for the manufacture of dry batteries.

As most of the manganese in Bessemer steel is added in the form of the low-grade manganese alloy spiegeleisen, and as the higher-grade ferromanganese is used in making open-hearth steel, it should be expected that the sum of the production and imports of these alloys should show a close relation to the production of Bessemer and open-hearth steels, respectively. This relation is shown in figure 1, which shows also the general decline in the production of Bessemer steel in the United States during recent years and the great advance in the production of open-hearth steel. The extent to which this displacement of one variety of steel by the other is due to factors of cost, on the one hand, and qualities of product, on the other, is probably a matter concerning which only steel metallurgists are competent judges. The same may be said concerning the possibility of using spiegeleisen instead of ferromanganese in the open-hearth process. There can be no doubt, however, that if imports of ferromanganese, as well as of the high-grade ores needed to make it, were shut off, considerable readjustment in either practice or plants would be necessary to maintain the present rate of production.

At present most ferromanganese is made by smelting in the common type of iron blast furnace a mixture of high-grade manganese ore with enough iron ore to make a product containing about 80 per cent of manganese and 15 per cent of iron. Recently a small tonnage of ferromanganese has been made in the electric furnace, but information at present available indicates that the electric process can compete with the blast-furnace process only where there are exceptionally favorable local conditions, such as the proximity of sources of ore to sources of cheap electric power. In both processes the losses of manganese in slag and flue dust and by volatilization are large. For both processes ore containing at least 40 per cent of manganese, less than 8 per cent of silica, and less than 0.2 per cent of phosphorus is desired.

Spiegeleisen is made in the blast furnace, and at present more than half of the amount produced is obtained by smelting manganiferous zinc residuum, which contains about 40 per cent of iron and 14 per cent of manganese. Spiegeleisen may be made from mixtures of high-grade manganese ore and iron ore, from manganiferous iron ore, and from manganiferous silver ore.

GENERAL CONDITIONS.

MANGANESE AND MANGANIFEROUS ORES.

For convenience in presenting statistics the United States Geological Survey recognizes four classes of materials that contain manganese. (1) Manganese ore, most of which contains more than 40 per cent of manganese, is used in making ferromanganese and dry batteries. (2) Manganiferous iron ore, most of which contains from 12 to 25 per cent of manganese, is largely used in making spiegeleisen, but some is mixed with high-grade imported manganese ore to make low-grade ferromanganese and some is used to make high-manganese pig iron. (3) Manganiferous silver ore, whose composition closely resembles that of manganiferous iron ore, is largely used as a flux by lead smelters, but from time to time large quantities are smelted to spiegeleisen. (4) Manganiferous zinc residuum is similar in composition to manganiferous iron ore and is smelted to spiegeleisen.

The following table shows the number of operators of manganese mines that reported to the Survey for 1912 to 1915 and the number that shipped ore during those years:

Operators of manganese mines in the United States, 1912–1915.

	1912		1913		1914		1915	
	Reported.	Shipped.	Reported.	Shipped.	Reported.	Shipped.	Reported.	Shipped
Alabama	1	0	1	0	1	0	3	1
Arizona	1	0	1	0	1	0	3	1
Arkansas	3	0	3	0	3	0	10	7
California	8	2	8	0	22	2	26	6
Colorado					1	0	7	1
Georgia	5	0	5	0	5	0	8	4
Maine	1	0	1	0	1	0	1	0
Maryland					1	0	1	0
Montana	1	0	1	0	1	0	2	0
New Mexico					1	0	1	0
Oklahoma							1	0
Oregon							1	0
South Carolina	1	1	1	0	1	1	1	0
Tennessee	4	0	3	0	4	0	7	1
Texas	2	0	1	0	1	0	1	1
Utah	2	0	2	0	2	0	6	2
Virginia	31	5	27	4	28	7	36	7
Washington			1	0	1	0	6	0
West Virginia					1	0		
	60	8	55	4	75	10	121	31
Ore shipped, long tons		1,664		4,048		2,635		9,709

The largest domestic production of manganese ore for a single year was but 34,524 tons in 1887, and since that year, except for several brief periods, the domestic production has declined rather steadily.

The average annual production from 1880 to 1915 was 10,645 tons. Although one mine is reported to have produced about 250,000 tons most of the product has come from many small mines worked intermittently. Information concerning many of the deposits indicates that they were formed by the accumulation near the surface of manganese originally disseminated in minute quantities through the adjacent rocks. In order to obtain a marketable product from most of these mines, the raw ore must be washed and concentrated. On account of the nature of the deposits and conditions in the industry, little ore is developed in advance of mining, so that the extent of the individual deposits is not accurately known.

In contrast with the domestic production, the imports of manganese ore, largely from India, Brazil, and Russia, have rather steadily risen in proportion to the production of steel. The extensive deposits of these countries are rich enough to permit the shipment of large quantities of ore without concentration. The subjoined table shows the relation of the production and imports of manganese ores and alloys to the production of steel in the United States. The table also shows that whereas Russia, India, and Brazil commonly contribute to the imports into the United States, each country in turn has supplied the largest quantity for short periods.

Manganese alloys and ore produced in the United States and imported from important foreign sources, 1890–1916, in long tons.

Year.	Steel.	Ferromanganese.		Spiegeleisen.		Manganese ore.				
	Production.	Production.	Imports.	Production.	Imports.	Production.	Total imports.	Imports from— Russia.	India.	Brazil.
1890	4,277,071					19,287	34,154			
1891	3,904,240					22,452	28,825			
1892	4,927,581					13,613	58,572			
1893	4,019,995					7,718	68,113	[a] 36,070	([b])	
1894	4,412,032					6,308	44,655	[a] 28,300		([c])
1895	6,114,834					9,547	86,111	[a] 55,987		
1896	5,281,689					10,088	31,489	[a] 3,600		
1897	7,156,957					11,108	119,961	38,910	17,400	12,083
1898	8,932,857					15,957	114,885	46,396	5,944	17,031
1899	10,639,857					9,935	188,349	73,397	17,950	28,115
1900	10,188,329	([d])	([e])	([d])	([e])	11,771	256,252	132,121	10,650	54,451
1901	13,473,595	59,639	20,750	231,822	26,827	11,995	165,722	32,600	11,000	48,029
1902	14,947,250	44,526	50,388	138,408	68,813	7,477	235,576	3,338	64,170	102,550
1903	14,534,978	35,961	41,519	156,700	122,015	2,825	146,056	5,576	35,960	76,910
1904	13,859,887	57,076	21,813	162,370	4,623	3,146	108,519	11,959	10,200	66,875
1905	20,023,947	62,186	52,841	227,797	55,457	4,118	257,033	24,650	101,030	114,670
1906	23,398,136	55,520	84,359	244,980	103,268	6,921	221,260	13,805	154,180	30,260
1907	23,362,594	55,918	87,400	283,430	48,994	5,604	209,021	1,000	95,300	52,922
1908	14,023,247	40,642	44,624	111,376	4,579	6,144	178,203	250	143,813	17,150
1909	23,955,021	82,209	88,934	142,831	16,921	1,544	212,765	14,486	145,140	35,600
1910	26,094,919	71,376	114,228	153,055	25,383	[f] 2,258	242,348	33,120	140,965	53,750
1911	23,676,106	[f] 74,602	80,263	[f] 104,013	20,970	[f] 2,457	176,852	19,103	103,580	41,600
1912	31,251,303	[f] 125,378	99,137	[f] 102,561	1,015	[f] 1,664	300,661	83,334	128,645	81,580
1913	31,300,874	[f] 119,495	128,070	[f] 106,980	77	[f] 4,048	345,090	124,337	141,587	70,200
1914	23,513,030	[f] 100,731	82,997	[f] 76,625	2,870	[f] 2,635	283,294	52,681	103,583	113,924
1915	32,151,036	[f] 144,260	55,263	[f] 114,556	200	[f] 9,709	313,985		36,450	268,786
1916	([g])	[h] 221,532	90,928	[h] 194,002		[i] 33,000	576,321		51,960	471,837

[a] Drake, Frank, The manganese ore industry of the Caucasus: Am. Inst. Min. Eng. Trans., vol. 28, p. 191, 1898.
[b] First shipment made from India.
[c] First shipments made from Brazil.
[d] Figures for ferromanganese and spiegeleisen combined prior to 1901.
[e] Figures for fiscal years only available prior to 1901.
[f] Marketed production.
[g] Figures not yet available.
[h] American Iron and Steel Institute.
[i] Estimated.

Deposits of manganiferous iron ores have been worked in several States. With the exception of those in the Lake Superior region, the ores from most of which contain less than 5 per cent of manganese and are therefore smelted to pig iron, most deposits of manganiferous iron ore in the United States have a geographic distribution similar to those of manganese ore. Many deposits yield material of both classes. The following table shows the number of operators of manganiferous iron and silver mines that reported to the Survey for 1912 to 1915 and the number that shipped ore during those years. The operators of those deposits in Marquette County, Mich., and Iron County, Wis., whose product is smelted to pig iron are not included in the table:

Operators of manganiferous iron and silver mines in the United States, 1912–1915.

	1912		1913		1914		1915	
	Reported.	Shipped.	Reported.	Shipped.	Reported.	Shipped.	Reported.	Shipped.
Arizona [a]							1	1
Arkansas	2	1	3	2	2	2	3	2
Colorado [a]	20	20	24	24	23	23	52	52
Georgia							1	1
Minnesota	0	0	2	1	3	2	10	3
Nevada [a]							1	1
Vermont	1	0	1	0	1	0	1	0
Virginia	2	2	3	0	4	4	6	6
	25	23	33	27	33	31	75	66
Ore shipped, long tons		51,517		85,603		98,265		185,238

[a] Manganiferous silver ore.

Manganiferous silver ore is derived largely from the Leadville district, Colo., where the weathered parts of lead-silver deposits contain sufficient manganese, iron, and silver to warrant shipment to lead smelters for use in fluxing. From time to time the Colorado Fuel & Iron Co. manufactures spiegeleisen from these ores. The manganiferous silver ore may be regarded as a by-product of the mining of the lead-silver ore of the district, for if the mines were not operated for that purpose it would not pay to extract the manganiferous ore.

Manganiferous zinc residuum is a by-product of the smelting of manganiferous zinc ore from mines near Franklin Furnace, N. J. After the zinc is extracted the residue is smelted to spiegeleisen. As zinc is the most valuable product, the output of the mines varies with the demand for zinc and zinc oxide.

As the approximate composition of each of these varieties of ore has been submitted by the shippers, it is possible to calculate approximately the amounts of metallic manganese which they contained. The sum of these amounts, which are shown in the table below, less the losses in reduction, which range from 15 to 50 per cent, gives a figure that represents approximately the amount of metallic manganese which would have been available if all the current domestic supply of ore had been converted to manganese alloys. Most of the Colorado and Nevada manganiferous silver ore was not smelted to manganese alloys, however, but was used as flux in smelting lead ore.

A part of the manganese ore and manganiferous iron ore was used directly to make dry batteries and other articles.

On the last line of the table are given the percentages of the total manganese needed by the domestic steel industry as alloys that could have been supplied by domestic deposits if all the ore had been reduced. According to this calculation, domestic deposits could have supplied during 1915 at most only one-fifth of the demand for manganese in alloys.

Manganese recoverable from ore produced in the United States, 1912–1915, in long tons.

Source.	1912		1913		1914		1915	
	Ore.	Manganese.	Ore.	Manganese.	Ore.	Manganese.	Ore.	Manganese
Manganese ore	1,664	799	4,048	1,943	2,635	1,265	9,709	4,660
Manganiferous iron ores *a*	2,899	580	35,850	6,646	58,384	10,732	48,193	9,040
Manganiferous silver ores	48,618	7,293	49,753	5,970	39,881	6,780	137,045	17,504
Manganiferous zinc residuum	104,670	13,701	102,239	13,996	100,198	14,438	159,318	23,053
		22,373		28,555		33,215		54,257
Manganese recoverable as alloys		15,023		19,096		22,312		36,792
Percentage of total manganese needed		7.5		8.8		13.8		21.0

a Exclusive of Marquette County, Mich., and Iron County, Minn.

FERROMANGANESE AND SPIEGELEISEN.

The ferromanganese needed for the American steel industry has been supplied in part by imports of the alloy itself and in part by domestic manufacture from imported ore. It is evident that the domestic manganese ore is the source of little ferromanganese. The available data for spiegeleisen, however, show that prior to 1914 about half of the domestic product was made from domestic ore. During recent years the imports of spiegeleisen have been negligible. The available supply of these manganese alloys for 1912 to 1915 and the approximate content in manganese is shown in the table on page 7. From these results, it has been calculated that for the four-year period an average of 14 pounds of manganese has been consumed for each ton of steel produced.

The number of makers of ferromanganese increased from 2 in 1912 to 5 at the end of 1914, and of spiegeleisen from 3 to 6.

Makers of manganese alloys, 1912–1915.

	1912	1913	1914	1915
Ferromanganese	2	2	5	8
Spiegeleisen	3	4	6	7

Available supply of manganese alloys in the United States, 1912-1915, in long tons.

	1912		1913		1914		1915	
	Quantity.	Manganese content.	Quantity.	Manganese content.	Quantity.	Manganese content.	Quantity.	Manganese content.
Imports:								
Ferromanganese	99,137	a 79,310	128,070	a 102,456	82,997	a 66,398	55,263	a 42,210
Spiegeleisen	1,015	a 183	77	a 14	2,870	a 417	200	a 36
Domestic production:								
Ferromanganese	125,378	b 98,430	119,495	b 94,342	100,731	b 79,408	144,260	b 110,134
Spiegeleisen	102,561	b 19,618	106,980	b 20,790	76,625	b 15,288	114,556	b 22,808
	....	197,541	....	217,602	....	161,511	....	175,189

a Percentage of manganese estimated. b Percentages of manganese submitted by makers.

PRICES.

The market price of ferromanganese in the United States appears to depend upon several factors. As about half of our supply of this alloy is imported from England, where it is made from imported ore, and as most of the remainder is made in the United States from imported ore, the price of ferromanganese depends in part on economic conditions in the countries which are the sources of ore and in England and on the demands of the steel industry in the United States.

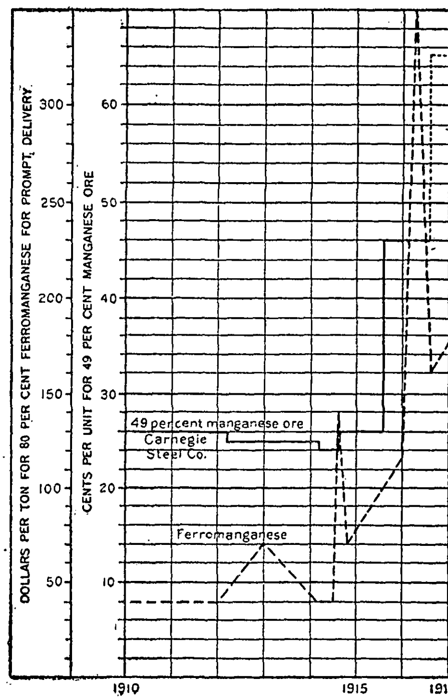


FIGURE 2.—Diagram showing prices of ferromanganese and manganese ore, 1910-1917.

Figure 2 shows the range in price per unit of 49 per cent manganese ore and of standard ferromanganese (75 to 80 per cent manganese) for prompt delivery from 1910 to 1917. Such a diagram can not show accurately the prices at which these materials are sold, because there is no established market for them, as there is for several other metals. The diagram shows that the price offered for 49 per cent ore from 1910 to 1914 ranged from 26 to 23 cents a unit, and for ferromanganese from $40 to $70 a ton.

CONDITIONS SINCE 1914.

MANGANESE AND MANGANIFEROUS ORES.

The first effect of the war in Europe was to reduce imports of ore from Russia and India. This reduction continued through 1915, but although Russian ore is no longer obtainable, imports from India were much larger in 1916 than in 1915.

In the United States the shortage of manganese ore did not greatly stimulate mining until 1915. For that year the number of shippers and the marketed production were three times those of 1914. At present there is a likelihood that the number of shippers and the marketed production for 1916 will be about three times those of 1915. Most of the increase in production for both these years was derived from deposits previously known. Recently discovered deposits in Arizona, California, Colorado, Nevada, Utah, Virginia, and Washington have been sources of production since 1914, but several of these deposits would probably have been exploited even had the war not developed a shortage. Little is known concerning most of the new deposits, except that several have shipped considerable ore. Many other discoveries are reported, but as the superficial exposures of manganese deposits are likely to be deceptive to casual observers, it would not be advisable to assume without further investigation that these new deposits will become sources of production. No manganese ore has been received from Russia since 1914, and imports from India are considerably below the normal. On the other hand, imports from Brazil and Cuba have greatly increased and more than make up for the loss of supplies from Russia and India.

The number of shippers of manganiferous iron ores was also greater in 1915 than in 1914, but the marketed production decreased. It is a coincidence that war should have come in Europe and a shortage of manganese ores have developed at a time when attempts were being made to exploit the manganiferous iron ores of the Cuyuna range, Minn. If the manganiferous zinc residuum of New Jersey is omitted, the shipments of these ores in 1914 contained more metallic manganese than all other shipments in the United States. As a result of the operations of a number of mines, large amounts of ore carrying from 10 to 20 per cent of manganese have been proved as reserves. This activity is obviously due to the high prices offered for manganese alloys and may cease if prices drop, but there is good reason for believing that sufficient ore from which spiegeleisen and low-grade ferromanganese can be made is available in case of need.

The shipments of manganiferous residuum during 1915 increased greatly over the average of previous recent years. The production of this material is dependent upon the output of zinc ore, and the reserves may not be readily available.

One direct result of the shortage of manganese ore has been the stimulus to miners of manganiferous silver ores to select portions of the ore rich enough in manganese to be more valuable for this metal than for their small gold and silver content. Thus, one mine in the Tombstone district, Ariz., is treating a fairly large quantity of the raw ore in mills and producing a concentrate rich enough in manganese to be used in making dry batteries and ferromanganese, while the tailing is shipped to smelters as a flux. In the Philipsburg district, Mont., high-grade manganese ore is being mined and shipped from the oxidized zones of gold and silver bearing veins that have never before been sources of manganese ore. In addition to the Leadville district, Colo., the Pioche district, Nev., has recently been the source of large shipments of manganiferous silver ore, which is largely used as a flux by lead smelters. There is little doubt that if the price of spiegeleisen were double that now offered a large part of the product of both districts would be used to make this alloy.

FERROMANGANESE AND SPIEGELEISEN.

As the war has made heavy demands on the steel industry of England, it is natural that her exports of products like ferromanganese should be curtailed. In fact, from November, 1914, to March, 1915, there was an embargo on the shipment of ferromanganese from England. The resulting shortage in the United States has been met by an increase in domestic production. So far as information is available, it appears that the increase has been accomplished by the entrance of new makers into the field, rather than by increase in the output of those already in it. The number of makers of ferromanganese in 1915 was eight, and there were several additional in 1916. The production of spiegeleisen has increased slightly, and several new makers entered the field in 1916.

PRICES.

The prevailing price of manganese ore has steadily risen since 1914, but the increases have lagged behind those in ferromanganese. For 15 years prior to 1914 the price per unit of 49 per cent ore in the United States ranged from 23 to 30 cents, but during 1916 it rose first to 45 cents and later to 65 cents. The price of 65 cents was maintained through the early months of 1917.

Soon after the war broke out the price of ferromanganese rose suddenly from \$40 to \$120 a ton for a brief period, then ranged from \$70 to \$115 for more than a year. During 1916 prices ranged from \$115 to \$175 a ton, except for a short time in April, when \$400 a ton was recorded. This great rise was probably caused by Germany's declaration of a blockade of England. In February, 1917, the price reached $250 a ton.

The price offered for standard 18 to 22 per cent spiegeleisen has also increased from about $25 a ton in 1914 to $50 in 1916 and $65 in 1917.

SUMMARY.

The preceding review of the trend of production, imports, and prices of manganese ore and alloys during the last three years of extraordinary demands, when several regular sources have been largely eliminated, leads to several conclusions. First, it is reassuring to know that even if Russian and Indian ores are largely eliminated, Brazil can supply the enormous quantity of high-grade ore that has been required. On the other hand, the meager response of domestic manganese mines to prices that are three times normal, though not wholly unsuspected, is a source of apprehension. Some new deposits have been found, but there is no assurance that they are larger than those previously known. There can be little doubt that if conditions demanded the maintenance of the 1916 output of steel and if imports of manganese ore and ferromanganese were shut off, the deposits of manganese ore now developed in the United States could not meet the demands, and much readjustment in the steel industry would be necessary.

In any industry shortage of material may develop either through actual deficiency of supplies or because it ceases to be profitable to produce the grades of raw material hitherto considered acceptable. In the case of manganese it appears that the United States faces the second situation. The supply of high-grade manganese ore is deficient, but there is reason for expecting that if the lower-grade manganiferous iron ore and materials of similar composition can be more widely utilized, an adequate supply of raw material can be obtained for several years at least. It is not clear what increase in price of manganese alloys would be necessary to bring forth the required supply, but it seems certain that the needs could be met by the combined output of manganiferous iron ore, manganiferous silver ore, and manganiferous zinc residuum.

There can be little doubt that, under necessity, the manganese and manganiferous iron deposits of Virginia, Georgia, Tennessee, and Arkansas can be made with little additional equipment to yield twice or three times the present output for several years. Undoubtedly, however, the deposits of the Cuyuna range, Minn., offer a greater supply in a smaller area, and as a number of mines are reported to be exploring that range in advance of production only small additions to equipment should be necessary to make large tonnages available.

The recent increase in prices of alloys has diverted for the manufacture of spiegeleisen large quantities of manganiferous silver ores that previously had been used only as flux. Mines at Leadville, Colo., and Pioche, Nev., have shipped a large aggregate quantity and will probably continue to ship, but in such districts explorations are rarely carried on greatly in advance of production. The ratios of iron, manganese, and siliceous matter in the manganiferous siderite from which the oxidized ores of Leadville appear to have been formed closely resemble those in other materials that are now smelted to spiegeleisen. Systematic investigation in Pioche, Leadville, and elsewhere may show that these districts contain large quantities of manganiferous siderite which may be smelted to spiegeleisen. Although manganiferous silver ore is being shipped by other districts, such as Tombstone, Ariz., Silver City, N. Mex., and Philipsburg, Mont., there is no prospect that they are capable of shipping as much as Leadville and Pioche. The most recent information from Eureka, Nev., and Tintic, Utah, does not encourage the hope for production from those districts.

The largest resources of manganiferous materials in the United States are those from which only spiegeleisen may be made by processes now in use. It would be well to inquire whether there is a prospect of making from such materials, by milling methods or preliminary smelting, a product rich enough in manganese to be smelted to ferromanganese. Most of the manganese ore now produced in the United States is subjected to washing and other processes of concentration, and some of the manganiferous silver ores of Tombstone, Ariz., yield by concentration a high-grade manganese ore. According to press reports, experiments are being made with ores from the Cuyuna range, Minn., with the hope of extracting a part of the iron minerals and thereby raising the manganese content of the remainder.

The suggestion has been made recently that it is possible to smelt manganiferous iron ores in such a way that most of the iron is reduced to metal and the manganese thereby concentrated in a slag from which ferromanganese might be smelted. It is possible that some ores might be treated in this manner, but as the silica of the ore would also be concentrated in the slag and the losses of manganese would reach a maximum when it is reduced from material with high silica content, it is doubtful whether such a process could be used profitably to make ferromanganese from most of the ores now available.

The possibility of using this or similar processes to make ferromanganese from materials not available by present methods must be weighed against the alternative of extending the uses of spiegeleisen to the manufacture of all kinds of steel, rather than to that of steel made by the Bessemer process alone. These questions require investigation by competent metallurgists, but it may serve a purpose to call attention to them. The problem of adequate manganese supply resolves itself into two parts—production, on the one hand, and utilization, on the other. Most manufacturers of steel are aware of the conditions that affect the current supplies of manganese ores and alloys, but it is possible that they have not adequately considered the prospect of utilizing other manganiferous ores. Of course, the need for using these ores will not arise until imports of high-grade ores have been stopped, but it is evident that experiments should be made now and that the steel makers are best equipped to undertake them.

In order to insure the maximum production of ores of all grades, the cooperation of competent economic geologists, mining engineers, and owners of manganese deposits is suggested. As the manganese deposits of the United States have not yet been able to supply large quantities of ore in competition with several foreign sources, the operation of most domestic manganese mines has ceased to be profitable, and much of the annual output is derived from brief campaigns of operation by optimistic investors who know little about the business and its risks. The mining of manganese ores therefore does not appear to attract the able engineers and workmen who make a success of mining iron ore and coal in the same or near-by regions. It is not impossible that the production of high-grade manganese ore might be made profitable and be increased three or even six times if the owners of the mines had the benefit of competent technical advice and supervision. It would be worth while to consider the advisability of procuring for the owners of properties more or less developed the cooperation of members of the Geological Survey, the Bureau of Mines, and the American Institute of Mining Engineers. Geologic reconnaissance of a number of new deposits by the Geological Survey and prospecting by individuals may also extend the known occurrences.

PLATINUM.

By James M. Hill.

USES.

Platinum has become a metal of war importance. Many are apt to think of this rare metal as preeminently adapted to settings for precious stones, and at present 50 per cent or more of the platinum used in this country is consumed in the jewelry trade. But the metal is of vital need to many industries upon which success or failure in war may depend.

Dishes and utensils of platinum are absolutely necessary in all chemical laboratories, and upon their laboratories all great industries are dependent for guidance. Several alloys of cheaper metals and china, glass, nickel, or gold can be used to replace some of the platinum for this purpose, but not all the platinum utensils can be replaced by substitutes.

Alloys have been developed for some parts of the ignition systems of internal-combustion engines, but no substitute for platinum has been found for certain delicate parts of the ignition systems, and to insure the proper operation of the automobiles, motor boats, and airplanes called into national service a large quantity of platinum must be available for this use.

Platinum or allied rare metals have wide application in many instruments of precision used in the physical testing of all kinds of materials.

Probably the use of platinum most closely connected with war is in the contact process of making concentrated sulphuric acid, an essential commodity to a great number of industries aside from the manufacture of munitions. An inquiry made by the United States Geological Survey showed that in 1915 a total of 43,888 ounces of platinum was in use in the contact chambers of domestic sulphuric-acid works, and it is probable that this amount was considerably increased during 1916 and will of necessity be further increased.

SUPPLY.

The world's supply of platinum is limited. Russia has furnished about 95 per cent of all the platinum produced, and Colombia has stood second.

As will be seen from the following table, the world's production of crude platinum has been diminishing since 1912.

Estimated world's production of crude platinum, 1909–1916, in troy ounces.

Country.	1909	1910	1911	1912	1913	1914	1915	1916
Borneo and Sumatra	500	200	....	....	200	(a)	(a)	(a)
Canada	30	30	30	30	50	30	100	60
Colombia	6,000	10,000	12,000	12,000	15,000	17,500	18,000	25,000
New South Wales and Tasmania	440	332	470	778	1,500	1,248	303	(a)
Russia	264,000	275,000	300,000	300,000	250,000	241,200	124,000	57,860
United States	672	390	628	721	483	570	742	750
	271,642	285,952	313,128	313,529	267,233	260,548	143,145	83,670

a No basis for estimate.

It will be noted that the normal annual addition of crude platinum to the world's supply has varied between 260,000 and 313,000 ounces. This supply is augmented by the platinum produced by refiners of copper matte and gold bullion. United States refiners of gold and copper produce annually about 1,500 ounces of refined platinum as by-products, chiefly from copper ore, of both foreign and domestic origin.

That the supply of new platinum has not been sufficient to meet the requirements is indicated by the very extensive trade in scrap or used metal. Figures are not available for such trade in foreign countries, but in the United States the yearly sales of secondary platinum normally amount to about 40,000 ounces; in 1916 they increased to 49,400 ounces.

Owing to scarcity of supplies and labor due to the war and to the derangement of the platinum market in Russia, her production during 1916 was much below normal. It seems probable that production after the war will not be materially increased over the normal rate, and it may even not come up to normal for some time. Duparc, an authority on Russian platinum deposits, has recently made the assertion that at the rate of production before the war began the known platinum deposits of Russia would become exhausted in 12 years.

Although the platinum deposits of Colombia have been yielding for many years, they have not been developed by engineering methods until recently. Prior to 1914 most of Colombia's platinum output was won by native miners with bateas (wooden pans), but at present a strong company controlled by Americans is developing its holdings with dredges, and the output for the future seems assured. Most of the platinum heretofore produced has come from the San Juan River drainage basin, but it is known that platinum occurs in the upper part of the Atrato River basin, and it would seem that systematic prospecting of the whole western slope of the Andes in Colombia should be undertaken with a view of increasing the world's supply.

The platinum production of the Australian provinces and of Borneo has been small. The deposits, to judge from reports, are nearly if not quite exhausted and do not hold much promise of great additions to the supply.

In North America platinum is produced from placers in British Columbia and from the copper ores of Sudbury, Ontario. There is a possibility that new placer deposits may be discovered among the western mountains, and reports have reached the Survey of platiniferous gravels as far north as The Pas, in Manitoba.

In the United States most of the small annual output of crude platinum has been won from the well-known placer deposits in California and southwestern Oregon, but a little has come from a gold-platinum-palladium lode in Nevada and a copper mine in Wyoming. The dredges in the foothills of the Mother Lode country have been the largest producers, but so far none of the stream placers in the serpentine belt that feed the dredge ground have been found to carry platinum in sufficient quantity to be economically important. In the auriferous gravels of Trinity, Salmon, and Klamath rivers, in northwestern California, and Illinois and Rogue rivers, in Oregon, platinum is more or less abundant. Much of this country has been prospected thoroughly for gold, but there is a possibility of finding streams in which the platinum has been overlooked. The beach placers on the Oregon and California coasts have also yielded platinum, and it may be possible to further develop this source of supply. Discoveries of platinum in the placer gravels of certain streams in Alaska have been reported from time to time, and in 1916 some platinum was shipped from the Territory.

POSITION OF THE UNITED STATES.

The United States at present is not supplying 10 per cent of its platinum requirements, and while there is some assurance that by systematic geologic investigation, already planned, new placer deposits that will yield platinum may be found and that by a study of the methods of saving platinum a greater yield from all deposits may be had, yet the issue must be squarely faced that in all probability the domestic supply can not be made adequate to meet the requirements of normal times.

An abnormal situation now exists, and it should be considered what steps are to be taken to assure an adequate stock of platinum for the essential uses of the Government. Early in the war England and

France commandeered all stocks of platinum for Government use, and all dealings in this metal in those countries have been closely controlled by the respective Governments. In the United States it has so far proved almost impossible to collect accurate statistics of supplies or production of this metal. It may prove necessary for the Government to commandeer supplies, but it should be possible to count on the patriotism of domestic platinum dealers and refiners to inform the Government fully of all available reserves of this metal. Fifty per cent or more of the platinum used in the United States has been made into jewelry, the larger part of which is now in private possession. It may be hoped that the whims of fashion will yield to national needs and that purchasers of jewelry will demand gold and silver or a white alloy and so release platinum for its highest use.

Steps should be taken immediately to ascertain the quantity of platinum in the United States that could be considered as an available supply, and to adopt some measures for obtaining an adequate reserve of the metal to meet the Nation's needs for war purposes. The needs of munition makers are at present probably supplied from reserves accumulated during the last two years, but the future demands of a the country are inadequately provided for.

GYPSUM.

By R. W. Stone.

CONDITION OF THE INDUSTRY.

The three years 1913–1915 saw no marked fluctuation in the gypsum industry. For some time the annual output has been near 2,500,000 tons of raw material. In 1913 the production was about 2,600,000 tons, and in each of the two following years there was a slight decrease, amounting in all to about 150,000 tons, a decline of less than 0.06 per cent. This decrease was due largely to a falling off in the demand for gypsum wall plaster occasioned by a reduction in the number of buildings constructed. Statistics of building operations in the leading cities of the United States show that 2,500 fewer permits were issued in 1915 than in 1914. This decline was probably due to the increase in cost of supplies and of labor reflected in the same statistics, which show that although the number of operations was less, the cost increased $22,000,000, or 3.55 per cent. Figures are not yet available (April, 1917) for the gypsum industry in 1916, but it is believed that the year was one of increased production. Prices of all supplies have increased, but bigger business requires and can pay for more building, and this condition has been favorable to the gypsum industry.

This particular industry could not suffer from restraint of ocean traffic, because the imports, which come wholly from New Brunswick and Nova Scotia, are normally only about one-fifteenth as much as the domestic production, and gypsum is so abundant and widespread in the United States that the nation is easily industrially independent in this respect.

Gypsum is produced in 18 States and Alaska. Most of the deposits are west of Mississippi River, but considerable quantities occur in New York, Virginia, Ohio, and Michigan. New York, in fact, is the largest producer, yielding 500,000 tons annually, or one-fifth of the country's total. Iowa ranks second and Michigan third. The most extensive deposits are in Wyoming, Utah, Texas, and New Mexico, where thick beds of high-grade gypsum crop out for hundreds of miles. In Wyoming alone gypsum beds from 6 to 20 feet thick are exposed for a thousand miles and constitute a reserve that the world's demands would not exhaust in many decades.

In 1915 there were 77 active mines or quarries which supplied 69 gypsum plants. A number of plants are standing idle. In case of greatly increased demand for gypsum products the idle plants could quickly be put into commission, and the active plants that are working only one or two shifts could be put on a 24-hour schedule, thus making a large increase in the output. The production of gypsum boards probably could not be so quickly increased as that of other products, because they are made on machines which are not on the market.

As the deposits of high-grade gypsum in the United States are widespread, practically inexhaustible, and in many places close to present lines of transportation, and as the milling part of the industry can easily be made to increase its output, the outlook for this popular structural material is fair even in times of worldwide unrest.

USES OF GYPSUM.

The principal uses of gypsum are as structural material and as an ingredient in Portland cement. Gypsum wall plaster is in common use, and gypsum boards, blocks, and tile are fast making a market because of their light weight, convenience, and fire-resistant qualities. Because of the rapidity with which the plaster sets, permitting carpenters to follow the plasterers within a few hours, and because of the size and shape of the gypsum block, tile, and board units, which favor quick construction, these materials are especially adapted to the hurried emergency building operations occasioned by great industrial activity.

At such times as the present, when many manufacturing firms, particularly those engaged in making munitions, are called upon to expand their plants in the shortest possible time, and when high fire-resistant qualities are demanded in the new buildings, gypsum products are used extensively, according to information of the United States Geological Survey. For quickly constructed one-story buildings which shall be warm in winter, cool in summer, and noninflammable a light steel frame with inner walls, roof deck, and partitions of gypsum block and slabs should be satisfactory. Gypsum should not be used for exterior construction in a moist climate but has been so used successfully in some of the arid portions of the United States. In steel-frame buildings several stories high the use of gypsum blocks for partitions and for fillers in concrete floors not only gives fire-resistant quality to the building and hastens construction but decreases appreciably the strength required in the frame. Furthermore, because gypsum dries rapidly, a building plastered with it can be occupied very soon after plastering is completed. In a number of buildings recently constructed at our navy yards gypsum slabs have been used for the roof decks because of their light weight and noncondensing quality.

Other uses of gypsum in time of war may be mentioned briefly. Gypsum is a constituent of the Portland cement used in the foundations and frames of buildings, in the construction of bridges, in fortifications, in the emplacement of heavy artillery, and for numerous other purposes in the maintenance and operation of the Army and Navy. It is suggested that for light-artillery emplacements a hard-setting gypsum plaster might be used. Gypsum is used advantageously as a fertilizer on some soils and with some crops and doubtless will be used in greater quantity under the present stress for a large yield from our farms. Calcined gypsum in the form of plaster of Paris is used for making casts around broken limbs and so has an important function in the surgical wards of hospitals, especially during war. Bandages for orthopedic surgery, used very extensively in hospitals, are made of gauze filled with plaster of Paris.

SALT, BROMINE, AND CALCIUM CHLORIDE.

By R. W. Stone.

SALT.

The United States furnishes practically all the salt consumed by its people. In 1916 more than 99 per cent of all the salt used in this country was made here, and the value of the salt exported was more than twice as great as that of the salt imported. The total quantity of salt produced has increased steadily for many years. The imports have taken a sharp slump in the last four years, and the exports have increased about 50 per cent in the five years preceding 1916. The imports and exports, however, form a very minor part of the industry. The marketed domestic production of salt in the United States has increased from 20,000,000 to nearly 40,000,000 barrels in 15 years and is now increasing at a much more rapid rate. The war in Europe has stimulated industries in this country that require salt for chemical or metallurgic purposes, with the result that the natural growth in demand due to increased population is augmented to a marked degree by industrial needs.

The production in 1916 is estimated at 43,000,000 barrels of 280 pounds, or nearly half a barrel for each individual in the country, compared with 38,000,000 barrels in 1915. For many years the mines and manufacturing plants have not been producing anything like their capacity, and the 5,000,000-barrel increase in 1916 is only an indication of what can be done if a demand arises for enlarged output. Most of the plants can largely increase their present yield. The rock-salt mines are capable of extension and already are so developed that only additional labor and machinery would be needed to double their output. Most of the solar evaporators could increase their acreage and consequently their production.

Prices of salt are increasing and may continue to increase so long as the present unsettled conditions continue. Some grades of salt have doubled in value since 1915; others have increased 50 per cent. This increase is chargeable not only to increased demands of labor and cost of supplies but also to the larger margin of profit to which producers feel entitled under present circumstances. Heavy charges against the cost of production are wages and fuel. Labor is demanding and receiving higher pay, and coal at some salt works has been hard to get and expensive. One producer reports coal increased in cost from 80 cents to $5.50 a ton.

The production of salt must continue, as for many years past, to increase. The use of salt in food for men and animals naturally demands enlarged output to keep pace with increased population; its use as a source of chlorine and hydrochloric acid and in many chemical and metallurgic industries that are rapidly developing also demands larger output, though some of these industries may be much less active after present hostilities cease. Attention to sanitation is spreading in great waves, even to remote districts, and carries with it a demand for glazes and enamel on pottery and hardware, and for refrigeration and preserving foodstuffs, all of which take large quantities of common salt.

Fourteen States reported production in 1915. Salt of all grades is made from the lump salt used in salting cattle to the finest table and dairy salt. Rock salt is mined in New York, Michigan, Kansas, Louisiana, and Utah. Salt is produced from natural and artificial brines obtained from wells in several States and from the waters of Great Salt Lake and of the Pacific Ocean. It is also obtained from deposits in playas in Nevada, Texas, and New Mexico. New York, Ohio, and Michigan are the main source of salt for the Eastern States, Kansas and Oklahoma for the Central States, Louisiana and Texas for the South, and Utah and California for the West. In each of these general localities the supply is apparently inexhaustible. In New York, for example, an area of 2,000 square miles in the central counties from Oneida Lake to Lake Erie is underlain with a rock-salt deposit whose thickness ranges between 8 feet and 318 feet. This deposit alone would supply the whole United States for thousands of years. The present production, both by mining and from artificial brines, is negligible in comparison with the latent possibilities.

In Kansas a deep well struck rock salt at 690 feet below the surface and penetrated 600 feet of rock salt in beds from 5 to 60 feet thick. A large area in this State is underlain by salt, which is mined by many shafts and obtained by pumping brine. Drilling for oil in Texas and Louisiana has revealed the presence of tremendously thick deposits of rock salt at a depth of a few hundred feet. Thicknesses of 2,000 feet are common, and one drill hole passed through more than 3,000 feet of rock salt. Most of the salt made in Utah is produced by evaporating the water of Great Salt Lake, and in California by evaporating sea water. These sources are inexhaustible, and the limit of production by solar evaporation will therefore never be reached.

BROMINE.

Bromine is made in connection with the manufacture of salt in Michigan at Mount Pleasant, Isabella County; at Midland, Midland County; near Saginaw and at St. Charles, Saginaw County; and at Bay City, Bay County; in Ohio at Pomeroy, Meigs County; in West Virginia at Mason and Hartford, Mason County; and in the Kanawha Valley at Malden, Kanawha County. In Michigan the bromine has been marketed in the form of fine chemicals, but the great increase in demand brought on by the war has caused a great deal of the bromine to be marketed as such. Along Ohio River, where there is cheap transportation by rail and water and cheap coal and gas and where salt and bromine occur naturally, bromine has been produced for export for many years to be made into fine chemicals. Here is an opportunity which the American chemist should not neglect.

The element bromine does not occur in native form but is derived in large quantities from natural brines. It is used as an oxidizer in many chemical reactions instead of chlorine and for dissolving gold and separating it from platinum and silver; also in disinfectants and bromine salts and in making aniline colors. Recently it has been extensively used in making the asphyxiating gases employed in the European war.

In 1915 there was a significant increase over the production of the previous year, the total output in the United States being 855,857 pounds, valued at $856,307, or about $1 a pound. The comparatively low price indicated by the total figures is due to the fact that considerable bromine was sold at prices specified in contracts made before the demand increased and to the further fact that the figures indicate prices at point of production and hence do not include the cost of freight. The price of bromine during the first half of 1916 ranged from $4.75 to $6.50 a pound in New York, as a result, at least in part, of the unprecedented demand from abroad. In March, 1917, it had fallen to $1.30 a pound.

As the quantity of bromine marketed in 1915 was an increase of nearly 50 per cent over the production of each of the two preceding years, and as the number of wells is few where there might be many, it is assumed that this quick response to a sudden demand is only a suggestion of what may be done in case of continued and increased demand. The statistics of production for 1916 are not yet available (April, 1917); it is believed that there was a very considerable decrease in the quantity of bromine made from natural brine but an increase in the total value of the product.

CALCIUM CHLORIDE.

Calcium chloride is made from natural brines at Mount Pleasant and Saginaw, Mich.; Pomeroy, Ohio; and Mason, Hartford, and Malden, W. Va. As the same brines yield salt and bromine, practically every constituent in them is turned to profit. Calcium chloride is used as the circulating fluid in refrigerating plants, in cement concrete, and in automobile gas-engine water jackets to prevent freezing, and, on account of its power of absorbing moisture, for laying dust on roads, drying gases, vegetables, and fruits, and dehydrating organic liquids. Calcium chloride in solution is especially valuable in automatic sprinkler systems and in fire buckets.

The quantity of calcium chloride produced from natural brines and sold in the United States has recently been about 20,000 short tons a year, valued at $6 to $6.50 a ton. This does not include the output obtained in the manufacture of soda, as calcium chloride so obtained is not an original constituent of brine. Large quantities made in the manufacture of soda have been wasted, and it is hoped that new uses may be found for this by-product.

Since the first half of 1916 there has been a demand for this material which has raised the price. In March, 1917, 70 to 75 per cent fused calcium chloride was quoted in the New York market at $26 to $30 a ton, and granulated calcium chloride has recently been quoted as high as $40 a ton. Fused lump calcium chloride that used to retail for 15 cents a pound was quoted in April, 1917, at 90 cents. It is believed that the supply can easily be kept ahead of the demand.

SAND AND GRAVEL.

By R. W. Stone.

ROAD MATERIAL.

Military preparedness includes in time of peace the construction of permanent trunk highways and in time of war the hasty improvement of roads that lead from military bases to the line of action. Improvement of roads under war conditions would in most places mean surfacing with a mixture of sand and clay or of sand, clay, and gravel. This material is abundant; in fact, there are few areas in the United States where a good supply can not be had within a reasonable distance. The United States Geological Survey is in touch with thousands of producers of sand and gravel, and many of its detailed geologic maps show the distribution of the deposits.

GLASS SAND.

The glass-making industry is in no way dependent on foreign supplies for its sand, salt cake, soda ash, and limestone. Our resources in these materials are ample. Most of the output of glass sand comes from a belt of States extending from New Jersey to Missouri. Illinois, Pennsylvania, and West Virginia are the largest producers, and Illinois leads, producing well over 500,000 tons, largely by disintegration of the friable St. Peter sandstone. California is the only State west of Oklahoma that produced glass sand in 1915.

Glass sand has formerly been brought to this country in ballast from European ports, but the present conflict cut off this small importation. The war, by unsettling general business conditions, for a number of months put a damper on the glass industry in this country. Later, however, business has increased, building operations are active, demanding large quantities of window glass, and furthermore glassware is now being exported in quantity to Europe and to the countries which the European glass industry formerly supplied. Consequently the glass industry is booming, and as a corollary the production of glass sand has increased. The output in 1916 approximated 2,000,000 tons and was thus larger than it has ever been. On account of the higher wages and the increased cost of machinery and of all supplies, particularly coal, the price of glass sand, which has been decreasing in the last few years, showed an upward tendency in 1916.

The glass-sand deposits in this country are very extensive and are found in many States. Many deposits of high-grade material are undeveloped. Quartz sand suitable for making cheap glass occurs in great quantity in the white dunes on the coast of California and along the shores of the Gulf of Mexico and in the white quartzite and sandstone in many parts of the country. Most of the glass factories in this country are located with relation to large supplies of the cheap fuel—natural gas—so that West Virginia, Pennsylvania, and the Ohio Valley contain most of them.

MOLDING SAND.

The new requirements of armament and munitions have caused foundries and machine shops to increase their output, and this activity is in turn reflected in the molding-sand industry. The total production in 1915 was 3,500,000 tons, more than two-thirds of which came from New Jersey, New York, Pennsylvania, and Ohio. This was 750,000 tons more than the output of 1914. The statistics for 1916 are not yet available (April, 1917), but it is confidently expected that they will show 4,500,000 tons produced in that year. This country has unknown quantities of molding sand of different kinds, such as that required for light and heavy iron and steel castings. The developed deposits are very largely in the Eastern States, because that is where most of the foundries are situated. As freight rates practically prohibit long-distance shipping of this heavy and cheap commodity, little search has been made for deposits in the Western States, where the demand for molding sand is small.

Up to 1914 molding sand was annually imported from France for use in casting bronze. The French sand is used for facing the molds, and as most of the casting done in it is art work, the curtailment would not seem to be serious in a time of national stress. In response to requests from importers of the French sand and from bronze molders the United States Geological Survey has sought for a domestic substitute and is now able to announce that sands which on preliminary tests prove to be satisfactory substitutes for the French molding sand have been found near Albany, N. Y., and Zanesville, Ohio. Bronze and brass castings made at Government arsenals and navy yards for many years have been poured in sand from the Albany district; commercial foundries and manufacturers use sand from Albany, N. Y., Windsor Locks, Conn., and several localities in Ohio for facing molds for brass and bronze castings that do not require the extremely fine finish of art work. The supply at these places is abundant, and the country seems able to meet any requirement in quality and quantity of molding sand.

ABRASIVE SAND.

Sand suitable for grinding and polishing, ranging from small gravel for use in sand-blast work on heavy castings to the fine material used for giving a polish, is abundant, and the country produces about 1,000,000 tons annually. Pennsylvania is the leading producer and in some years furnishes one-half of the output. The present activity in the production of armament will call for an increased production of this material, for it is the practice in large foundries to clean castings by sand-blast.

GENERAL CONDITIONS.

The sand industry in all its branches grows normally with increase of population. Severe business depression decreases the production of building sand more than that of sand for some other uses, such as engine sand, which is used wherever trains and trolley cars run. Business acceleration increases the output and use of all kinds of sand. The value of all the sand and gravel produced in 1915 of which the United States Geological Survey has a record was over $23,000,000. The statistics for 1916 are not yet available (April, 1917).

AID BY GEOLOGICAL SURVEY.

An important part that the United States Geological Survey plays in the sand and gravel industry, aside from collecting and publishing statistical data, consists in answering questions regarding the usefulness of samples submitted for examination and directing inquirers to a source of supply of sands for special use. For example, within a few days after this country declared its participation in the war the Geological Survey directed an important laboratory to sources of glass sand for optical purposes, for which it was specified that the sand must contain less than 0.05 per cent of iron and over 99 per cent of silica; an importer of bronze molding sand was informed of localities in this country that can furnish a satisfactory substitute; and a maker of egg-boiling timers who can no longer procure the customary foreign sand was furnished with samples made by the Survey from domestic sand which fill the specifications calling for round grains passing 150 mesh.

127972°—19——4

ASBESTOS.

By J. S. Diller.

PRODUCTION AND PRICES.

The United States is one of the largest manufacturers of objects made from asbestos, but it is not a large producer of crude asbestos. The supply of asbestos of all grades in Quebec, Canada, is so large and so conveniently obtained and the quality of the Canadian asbestos is so excellent as to delay the development of asbestos deposits in the United States. The demand for high-grade asbestos has always been active, but recently, under the stimulus of war conditions abroad, it has become still greater, and the available supply, although larger than before, is frequently not equal to the demand. In 1916 the total output of asbestos in the United States was 1,479 short tons. The imports during the same time, almost wholly from Canada, amounted to 116,162 short tons, making a total supply available for manufacture in the United States of 117,641 tons.

Asbestos imported into the United States in 1916.

[Figures furnished by Bureau of Foreign and Domestic Commerce, Department of Commerce.]

Country.	1915			1916		
	Unmanufactured.		Manufactured (value).	Unmanufactured.		Manufactured (value).
	Quantity (short tons).	Value.		Quantity (short tons).	Value.	
Austria-Hungary			$10,502			
British South Africa				112	$10,625	
Canada	93,565	$1,980,749	1,867	114,978	3,069,617	$1,841
Colombia						109
Cuba			538			
Denmark			49			
England			106,412	1,072	223,228	119,123
France			139			10,762
Germany	1	734	14,117			100
Japan						298
Italy			2,624			2,538
Netherlands			190			
Scotland			879			293
	93,566	1,981,483	137,317	116,162	3,303,470	135,064

Five States now produce asbestos—Arizona, California, Idaho, Georgia, and Virginia. Arizona and Georgia are the largest producers—Arizona of high-grade fiber, and Georgia of fiber below the spinning grade.

The prices for asbestos produced in the United States during 1916 are said to have ranged, according to grade, from $15 to $1,000 a ton. In 1915 normal prices ranged from $10 to $400 a ton.

ARIZONA.

The asbestos of Arizona is chrysotile and occurs in serpentine associated with limestone altered by intrusions of diabase. As the strata are nearly horizontal, they are for the most part best exposed on the sides of canyons throughout the State. The cross-fiber veins of chrysotile are commonly parallel to the bedding of the limestone but are very irregular in their distribution, a fact which results from the irregularity of the contact between the limestone and the intruding diabase. The asbestos has to be won by tunneling into the canyon wall. As the amount of asbestos at any one place is small, thus limiting the production, the cost of production is increased, but in obtaining the best grade a considerable amount of valuable short fiber is accumulated on the dump and is available for future milling.

The asbestos of the Arizona mines is of two grades; one is very fine, soft, silky fiber of first-class textile quality, and the other is not suitable for textile manufacture. Although the second grade may have great length, it is harsh and when put through textile processes creates a good deal of "splint," which makes a rough-looking yarn altogether unsuited for higher textile uses. Both grades may occur in the same mine. The lower grade appears to be the more abundant, and the available quantity of first-class textile fiber is thus limited. The small percentage of iron contained in the best grade of Arizona fiber compared with Canadian fiber renders that of Arizona especially useful for its electric insulating qualities. As the whole mass of available good fiber is small, it should be mined with particular care to avoid waste. The limit of the asbestos field of Arizona is not yet known. The output will probably never be large compared with that of Canada, but under proper management the deposits may yield say 1,000 tons of valuable fiber annually for years to come.

CALIFORNIA.

The Klamath Mountains, Coast Range, and Sierra Nevada, in California, are rich in serpentine, and in places this rock contains considerable asbestos. The only producing point in 1916 was on Mears Creek, near Sims, in Shasta County, from which 3 carloads were shipped to an asbestos factory in Oakland. There is no fiber of spinning grade at this locality, and as the demand for the fiber mined is small the mining operations have not been extensive. The mine is within a few miles of the Southern Pacific Co.'s main line, and good water power for milling the fiber is available in Mears Creek. The serpentine is cut by a variety of dikes in the vicinity of the asbestos deposits. Cross-fiber veins of asbestos half an inch or less in thickness are common, and a prominent vein of slip fiber occurs on the same slope. There is considerable asbestos near the head of Mears Creek, and if there were a large demand for the lower grades of fiber a mill on this stream could do much toward meeting it.

Other prospects of asbestos in California that have attracted attention occur in Napa County near Canyon station on the stage road from Napa to Monticello, in Placer County, near Towle and Iowa Hill, and in Calaveras County near Valley Spring.

IDAHO.

In the vicinity of Kamiah, Lewis County, Idaho, there are rocks made up wholly of asbestos arranged in fibrous bundles. The fibers are short and brittle and are consequently far below spinning grade and suited only for use as a filler in the manufacture of heat-resisting or fireproofing covers, cements, or paints. There is only one producer at present. The demand is slight, but the supply of asbestos is large and the material is easily quarried, as it constitutes the whole mass of the rock. It occurs within a dozen miles of a railroad, 186 miles southeast of Spokane, Wash.

GEORGIA.

The asbestos mine near Sall Mountain, Ga., with a mill at Gainesville, has for years been the largest producer of asbestos in the United States. The asbestos, like that of Kamiah, Idaho, is of the mass-fiber type of anthophyllite, which forms fibrous bundles and constitutes the whole mass of the rock. Only the surface portion of the rock mass, which has been softened by weathering, is milled for fiber. The solid, unweathered portion of the rock is too hard for successful milling, and unless some way can be found to treat this portion successfully this limitation will greatly reduce the reserve for future needs. Georgia is far south of the glacier-swept region, and the mantle of residual softened rock is unusually deep, so that there still seems to be a fairly good supply for the near future.

VIRGINIA.

Rocks similar to those that furnish the asbestos in Georgia are common in the mountain region of North Carolina and Virginia, and in the latter State there is a very small production of asbestos used in manufacturing a dental product.

VERMONT.

The country rocks of the asbestos deposits in Quebec, Canada, extend southwestward into Vermont, where they contain considerable bodies of chrysotile that was mined more or less successfully a few years ago. The Vermont area contains very little spinning fiber but a considerable quantity of good milling fiber, and it is now attracting much attention. No production has yet been made. Although in the production of chrysotile asbestos Vermont can not compete successfully with Canada, the material in Vermont should be regarded as a valuable reserve if the Canadian deposits were not available.

WYOMING.

The asbestos deposits of Wyoming are largely chrysotile, but they contain only a trace here and there of fair spinning fiber. They have attracted much attention for years, especially from a speculator's point of view, but have not yielded a production. The possibilities of the region are not yet fully known. They should be tested and developed by an experienced manufacturer of asbestos who needs raw material. There is no doubt that a large amount of good-grade mill fiber occurs in that part of the country, including the Laramie, Wind River, and Big Horn mountains, which is so situated with reference to transcontinental as well as Great Lakes and Gulf traffic as to be readily accessible.

CONCLUSION.

With a view to increasing the available supply of asbestos, especially the spinning grades, which are so much in demand, all areas of peridotite and pyroxenite rocks more or less altered to serpentine should be prospected for cross-fiber veins of asbestos in which the fibers are three-fourths of an inch or more in length. The content of such fiber necessary to yield a profit may be less than 1 per cent of the whole rock quarried, and in obtaining it a much larger percentage of mill fiber will most probably be taken out.

Although the Arizona chrysotile fiber is excellent for certain purposes and finds a ready sale to those who need it for electric insulation, its mode of occurrence necessitates expensive operation and small production, and it should be mined with especial reference to avoiding waste and obtaining all within reach.

The origin of asbestos, especially that of Arizona, is not well understood, and much field investigation is needed to discover the causes determining its distribution and the best methods of mining so as to utilize as far as possible all the available grades of fiber.

The United States, being the largest manufacturer of asbestos and having only a meager domestic supply, has to depend very largely upon imported asbestos, but fortunately the chief source, which is Canada, is close at hand. Under increased demand the output of the United States is likely to be greatly augmented, although it can hardly be expected ever to supply all the asbestos needed for increasing manufacture.

TALC AND SOAPSTONE.

By J. S. Diller.

TALC.

The commercial deposits of talc are those of the relatively pure mineral. The massive rock composed chiefly of talc is considered under "Soapstone."

The United States is by far the largest producer and consumer of talc in the world. The softness, absorptive capacity, difficult fusibility and solubility, and electric resistance of talc make it one of the most generally useful of all minerals in the arts and industries. Its principal military use is in the ground form as an aid to the prevention of sore feet in marching under service conditions. For this purpose it should be pure.

Talc sold in the producing States in 1915 and 1916.

State.	1915		1916	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.
1. New York	88,214	$864,843	93,236	$961,510
2. Vermont	61,997	406,652	73,215	501,175
3. Pennsylvania and New Jersey	7,989	56,466	8,222	59,331
4. Virginia	3,036	18,579	8,798	73,622
5. Georgia and Massachusetts	2,934	25,971	6,921	111,686
6. North Carolina	1,454	21,501	1,787	41,824
7. California and Maryland	712	7,185	1,130	13,694
	166,336	1,401,197	193,309	1,762,842

Ground or manufactured talc imported into the United States, 1915 and 1916.

[Figures furnished by the United States Department of Commerce.]

Country.	1915		1916	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.
Austria-Hungary	138	$3,019		
British South Africa			10	$124
Canada	4,797	57,961	5,964	75,029
England			1	38
France	3,734	19,253	3,570	20,791
Germany	8	1,888		
Italy	7,268	104,403	7,105	121,254
Spain			11	400
Sweden			22	544
	15,945	186,524	16,683	218,180

The total domestic production is nearly twelve times the total imports, over one-third of which came from Canada. The talc of New York is an especially good paper filler and is largely used for that purpose, although much goes into paints. The output of Vermont is used for the same purpose and also for foundry facing, rubber goods, and coating walls. A small amount is used for crayons. Talc for pencils, crayons, burners, and insulators comes almost wholly from North Carolina and Georgia and is cut in Chattanooga. The demand for talc of the highest grade is greater than the supply. Much of the material for toilet powders is imported. With the exception of compact material for pencils, burners, and insulators and the best grade for toilet powders the United States has a large reserve in nearly all the producing States. It is believed that by more searching field investigations the domestic output even of pencil and gas-burner talc as well as the best toilet-powder grades may be greatly increased. The "foot-ease" grade of ground talc, now so extensively used in the Army, may be fully supplied in this country. Although the war has greatly stimulated production it has not greatly increased the price except in emergencies.

Some good specimens of more or less schistose white talc have been sent from Brazil to the United States Department of Commerce. The best grade appears to be suitable for making toilet powder and is said to come from a locality near Rezende, 75 miles by rail northwest of Rio de Janeiro.

SOAPSTONE.

Soapstone is a massive rock so rich in talc as to have a soapy feel. It is more extensively quarried and used in the United States than in any other country. Its principal use, which is due to its resistance to heat, acids, and electric conductivity, is in the manufacture of laundry tubs, laboratory table tops, tanks, sinks, fume hoods, switchboards, and general insulation. It also has many smaller uses growing out of its slow radiation of heat. In 1916 there was a small production of soapstone in California, but almost the entire output of the United States came from Virginia, where there were four producing quarries. The total yield, including that of California, was 19,652 short tons.

The rock from which the soapstone in Virginia is obtained forms a large belt of intrusive rocks extending northeastward through Nelson, Albemarle, and Orange counties. This large intrusive mass will afford an abundant supply for many years to come. It is near several railroads and James River and within easy reach of Chesapeake Bay and therefore has the advantage of adequate facilities for transportation.

The United States has large reserves of soapstone and can, if necessary, greatly increase its output.

PHOSPHATE ROCK.

By R. W. Stone.

Prior to 1914 the United States was producing annually close to 3,000,000 tons of phosphate rock, of which over 99 per cent came from Florida, Tennessee, and South Carolina. Florida produced more than 75 per cent of the total output, including the great bulk of the material exported, which was over 40 per cent of the total. With the beginning of the war the facilities for shipping phosphate rock to Europe were greatly decreased. Many Florida plants were shut down, and they have not resumed operations.

The proportion of exports to total production dropped from about 42 per cent in 1912 and 1913 to 35 per cent in 1914 and less than 14 per cent in 1915. In 1915 the total production was only 60 per cent of that in 1913. In 1916 the industry was in some areas practically demoralized, but there was nevertheless a gain over 1915. The total output in 1916 was 1,980,000 tons, valued at $5,897,000.

Percentage of phosphate rock produced, by States, 1912–1916.

State.	1912	1913	1914	1915	1916
Florida	81.0	82.0	78.0	74.0	76.0
Tennessee	14.2	14.5	18.0	21.0	21.0
South Carolina	4.4	3.5	3.9	4.5	2.7
Other States	.4	.2	.1	.5	.3
	100.0	100.0	100.0	100.0	100.0

As shown by the table, Tennessee, in spite of decreased production, has produced a larger proportion of the country's output since the war began than in time of peace. It would seem as if the Tennessee industry, which has not been bound up so much in the export trade and which is equipped in part with modern machinery for mining by modern methods, should develop while the European trade is restricted and while the industry in Florida and South Carolina is more or less dormant.

The deposits of phosphate rock in the United States are confined very definitely to the southeastern part of the country and to the

Rocky Mountain region from the latitude of Salt Lake City, Utah, to that of Helena, Mont. Although by far the largest deposits are in the Western States, the production from that region is less than 1 per cent of the whole, owing to the lack of a large market in the region at present and to high freight rates on the crude rock. The western rock-phosphate deposits are so extensive that, even if the entire world depended on them for its supply of phosphate, they would not be exhausted in many generations.

The Florida phosphate deposits comprise three classes of phosphate—hard rock, land pebble, and river pebble. The hard rock is the highest grade, the land pebble is produced in the largest quantity, and the river pebble is not mined at present. The area of hard-rock deposits forms a narrow strip along the western part of the Florida Peninsula from Suwannee County to Pasco County, a distance of approximately 100 miles. The land-pebble phosphate area lies just east of Tampa and is about 30 miles long from north to south and 10 miles wide. The sales of Florida phosphate have decreased greatly since 1913. In that year 2,500,000 tons was sold for $9,500,000; in 1915 the production was 1,350,000 tons, valued at $3,700,000. In 1916 the industry began to recover, and the output was over 1,500,000 tons, valued at $4,170,000.

The South Carolina output consists of land-rock phosphate mined in the vicinity of Charleston. River-pebble phosphate occurs in the same area but is not mined. Some of the South Carolina output has been exported annually. The sales have decreased from 169,000 tons in 1911 to 53,000 tons in 1916, and the value from $673,000 to $211,000.

The Tennessee deposits of rock phosphate are in the west-central part and extreme northeast corner of the State. The latter have not been mined. Three types are recognized and known by their colors as brown, blue, and white rock. The white rock has not been mined recently. The brown rock comes from Maury, Giles, Hickman, Lewis, and Sumner counties and is sold under a guaranty of 70 to 80 per cent tricalcium phosphate. The blue rock is mined in Lewis and Maury counties and varies considerably in its phosphatic content. The sales of Tennessee phosphate dropped from 483,000 tons, valued at $1,823,000, in 1914 to 390,000 tons, valued at $1,328,000, in 1915. In 1916 there was a partial recovery, the output being nearly 412,000 tons, valued at $1,510,000.

The phosphate deposits of Kentucky lie between Frankfort and Lexington, and considerable quantities of rock have been mined near Wallace, but the State has been an insignificant producer of phosphate rock in recent years.

Phosphate deposits occur more or less interruptedly for a distance of 80 miles in the north-central part of Arkansas, and a small quantity is produced at Anderson, Independence County.

Four of the Western States possess vast deposits of high-grade rock phosphate, but the western production amounts to only 3,000 to 5,000 tons a year. In 1916 it was only 1,700 tons. Idaho, Utah, and Wyoming are the producers. Montana is not yet a producer, although at Elliston, Garrison, Philipsburg, and Melrose there are very extensive deposits easy of access and close to rail transportation. The small local demand for fertilizer and lack of cheap transportation will for some years retard the development of these western deposits.

In the southeastern part of Idaho an extensive supply of high-grade phosphate occurs along both sides of Blackfoot River, in Fort Hall Indian Reservation, near Montpelier, and north of Bear Lake. A small quantity is mined in Bear Lake County.

The Utah deposits are east of Great Salt Lake, in the Wasatch and Uinta ranges, and east of Bear Lake. These deposits are extensive, but the material is leaner than the general run of Idaho phosphate, averaging nearer 60 per cent than 80 per cent tricalcium phosphate.

Western Wyoming also is rich in rock phosphate. The deposits are mostly in the Owl Creek, Wind River, Gros Ventre, and Salt River ranges. Some of them are thick beds carrying 80 per cent tricalcium phosphate and extending for many miles, and they constitute a reserve supply that is almost inexhaustible.

An estimate of the quantity of rock phosphate available in the United States was made in 1915 by the United States Geological Survey and need not be revised to account for that mined in the meantime. It is repeated here.

Estimated quantity of phosphate rock available in the United States.[1]

	Long tons.
Eastern States:	
Florida	227, 000, 000
Tennessee	88, 000, 000
South Carolina	9, 000, 000
Kentucky	1, 000, 000
Arkansas	20, 000, 000
	345, 000, 000
Western States (Montana, Idaho, Utah, and Wyoming)	5, 367, 000, 000
	5, 712, 000, 000

Although the total reserves as shown by this estimate are very large, the supply of high-grade rock is much less and should not be considered inexhaustible. Lands remaining in Government owner-

[1] Phalen, W. C., Phosphate rock in 1915: U. S. Geol. Survey Mineral Resources, 1915, pt. 2, p. 238, 1916.

ship that are known or believed to contain valuable phosphate deposits have been temporarily withdrawn from entry. The outstanding withdrawals are about 2,500,000 acres in the Western States and 120,000 acres in Florida. The work of surveying the western phosphate lands is still going on.

Any statement as to probable developments in the phosphate industry when peace is declared is largely conjecture. So long as the war continues phosphate rock can not be sent to the large consumer, Germany, and high ocean freight rates greatly restrict and practically stop shipments to other European countries. Furthermore, the demand for sulphuric acid for use in making munitions has raised the prices of acid so high that manufacturers of acid phosphate have been obliged to curtail production. This has reduced the quantity of rock phosphate used by manufacturers of fertilizers and increased the quantity of rock ground for direct application to the soil. It seems reasonable to believe that at the end of the war European nations will want increased quantities of phosphate, for their stores of foodstuffs will be low and intensive cultivation of the soil will be necessary. The demand will again fall largely on the Florida and South Carolina deposits, which are close to the seacoast, and the phosphate industry in those States may then look for marked improvement.

GRINDING AND POLISHING MATERIALS.

By F. J. Katz.

Investigations by the United States Geological Survey show that domestic resources can adequately supply domestic demands for all materials used for grinding and polishing except diamond dust and bort. The American industries requiring millstones, grindstones, pulpstones, oil stones, whetstones, scythestones, corundum, garnet, silica, feldspar, diatomaceous earth, and tripoli have long been independent of foreign supplies, and the developed domestic sources of supply are capable of greatly increased production. The imports of these materials have been small in comparison with domestic production and have very probably been fostered only by a natural preference and conservatism in favor of articles that had long been used before the American supplies came into the market. This conservatism will be forcibly broken down in the event of further difficulty of intercourse with Europe, and the domestic or Canadian materials will be satisfactory in quality and ample in quantity to supply all our needs.

On the other hand, American emery seems to be inferior to and unable to supplant the emery from Naxos, Greece, imports of which have been very largely shut out. Artificial carbide and aluminum oxide abrasives can be substituted, but some manufacturers, particularly lens grinders, seem to be reluctant to make a change, probably because it would involve changes in technique. Necessity must overcome such reluctance.

Corundum for a number of years has been supplanted by the artificial abrasives. Very recently, however, there has been a small revival in corundum mining. In the southern Appalachian and Piedmont provinces and elsewhere there are deposits of natural corundum which are well known and abundant,[1] and these may be worked whenever conditions warrant. It seems that about 3 to 5 per cent of the bauxite produced in the United States has been used in the manufacture of abrasive materials. A heavy increase in the demand for metallic aluminum may divert to aluminum extraction the bauxite

[1] See Pratt, J. H., Corundum and its occurrence and distribution in the United States: U. S. Geol. Survey Bull. 269, 1906.

ores that have been used in the manufacture of artificial abrasives. However, bauxite ores of lower grade than those in use are available for excess demands, and it does not seem probable that the manufacture of artificial aluminum oxide abrasives would be inhibited by an unusual demand for metallic aluminum. If it is, dependence will have to be placed on natural corundum for a very large proportion of the abrasive materials used in the metal trades, and such dependence will undoubtedly involve increased costs and difficulties of readjustment.

No domestic source of satisfactory lump pumice has been exploited commercially. Deposits of such material are known in Utah and southern California and in the Crater Lake region of Oregon. Probably there are many others in the Western States, but no information is at hand concerning the quantity and quality of such material, and doubtless much of it is far from transportation routes. Fortunately little of the imported pumice is used in the lump form. The ground or powdered material is chiefly in demand, and this can be satisfactorily and wholly supplied by the pumice dust or so-called volcanic ash that is extraordinarily abundant in the central part of the United States. This pumice dust has been adequately meeting the situation created by interference with shipping from Mediterranean ports.

The country remains dependent on foreign sources for diamond dust and bort, imports of which in the last three years have been about 25 per cent less than the average during the previous three years.

Up to 1914 the United States had been dependent on Europe, chiefly Denmark and France, for its supply of flint pebbles, which were used in grinding mills and were also crushed and ground for use in the body of ceramic wares. "Flint" blocks cut to specified dimensions for use in lining tube mills had also been supplied to American trade from foreign sources only. Late in 1914 and in 1915 the prices of these imported materials advanced in anticipation of difficulty in obtaining adequate supplies. This condition stimulated search for American flints or flint substitutes and led to suggestions by the United States Geological Survey as to possible sources of domestic supply.[1] Since 1914 domestic substitutes for flint pebbles have been introduced, and there is at present every promise of complete independence of European supplies. The pottery industry does not need ground flint, inasmuch as pure silica from other sources is equally satisfactory and has long been used by American potters. American sources of silica, such as clean sands, sandstones, quartzites, and vein and pegmatite quartz, are practically unlimited and widely distributed, so that they are readily available in all markets. The pottery

[1] Our mineral reserves: U. S. Geol. Survey Bull. 599, pp. 38–40, 1914.

industry, however, is in need of siliceous pebbles for grinding quartz and feldspar in tube mills. Substitutes that contain even small quantities of iron can not be used. This need may be supplied from the gravel deposits that are particularly abundant in the Gulf States and Arkansas. Gravel composed of flint or chert pebbles has been noted in many places, and some of the gravel deposits in Arkansas contain abundant novaculite pebbles, which will be satisfactory substitutes for the imported flint pebbles. No effort has been made, however, to develop these deposits, partly because the imports of Danish or French pebbles have not yet been short enough or the foreign pebbles have not yet increased enough in price to force the development of domestic supplies.

Metallurgic plants and cement mills have used a far larger quantity of flint pebbles than the pottery industry. The pure silica pebble is not required for them, the only essentials being toughness and hardness. For these purposes there are large quantities of suitable granite and porphyry pebbles in many localities along the New England coast which have not yet been drawn upon. During 1916 approximately 6,000 tons of pebbles were shipped from the coast of San Diego County, Cal., to metallurgic plants and cement mills, where they have proved to be entirely satisfactory and have cost far less than imported flint pebbles. Some grinding plants are using lumps of hard ore or other rock to supplant either in part or wholly the pebbles formerly used. Some of the Nevada gold mills are being supplied with artificially rounded blocks of chalcedonized rhyolite. Finally the use of steel and steel alloy balls, instead of pebbles, is on the increase. It is thus evident that American cement and metallurgic industries could do entirely without a supply of foreign flint pebbles.

Dimension blocks cut from quartzites in Florida, Tennessee, and Iowa have appeared on the market during the last two years and seem to be satisfactorily supplanting foreign flint lining.

GRAPHITE.

By Henry G. Ferguson.

INTRODUCTION.

Natural graphite may be either crystalline or amorphous. Crystalline or flake graphite is commonly understood to mean graphite in crystals of sufficient size to be visible to the naked eye; much of the so-called amorphous graphite shows a crystalline structure under the microscope. Crystalline graphite occurs either in veins, as in the Ceylon deposits, or as flakes disseminated through the country rock, as in many of the deposits in the United States.

Most deposits of amorphous graphite are the result of the alteration of coal beds by the intrusion of igneous rocks. Amorphous graphite s also made artificially by means of the electric furnace.

The peculiar physical properties of graphite—infusibility, chemical inertness, high conductivity, extreme softness, and low specific gravity—fit it for a large number of uses, such as the manufacture of crucibles and other refractory products, lubricants, "lead" pencils, paint, oundry facings, as a preparation to loosen boiler scale, as a polish for gunpowder, and in various types of electrical work. Of these uses the manufacture of crucibles takes by far the greatest share of the total output.

CRYSTALLINE GRAPHITE.

GENERAL CONDITIONS.

For most purposes amorphous graphite, either natural or artificial, may be used with as good effect as the crystalline variety, but for the manufacture of crucibles it is essential that the flakes be of sufficient size to add to the binding power of the clay with which the graphite is mixed. Graphite for crucibles should carry a considerable proportion of flakes 1 millimeter or more in diameter. The great increase in the manufacture of brass and crucible steel since the outbreak of the

---

Note.—Much of the material in this article is derived from the Geological Survey reports on graphite by Edson S. Bastin, particularly the report for 1913 (Mineral Resources, 1913, pt. 2, pp. 181-251, 1914) and "Geology of the graphite deposits of the United States" (Bull. 679, in preparation).

war has resulted in a tremendous increase in the demand for crystalline graphite. This demand has been met for the most part by largely increased imports, particularly from Ceylon, and only in minor part by expansion of the domestic graphite industry. The following table shows the imports and domestic output of crystalline graphite for the last six years:

Crystalline graphite imported and produced in the United States, 1911–1916.

Quantity (short tons).

	1911	1912	1913	1914	1915	1916
Imports:[a]						
Ceylon	13,119	16,791	16,996	8,755	14,491	24,984
Other countries	2,384	2,819	2,382	2,328	4,504	7,122
	15,503	19,610	19,378	11,083	18,995	32,106
Domestic production	2,395	1,772	2,532	2,610	3,537	5,468
Total available supply	17,898	21,382	21,910	13,693	22,532	37,627
Per cent represented by domestic production	13.4	8.3	11.6	19.1	15.7	14.68

Value.

	1911	1912	1913	1914	1915	1916
Imports:[a]						
Ceylon	$1,132,678	$1,379,587	$1,674,764	$962,593	$1,746,153	$6,013,366
Other countries	83,124	127,347	160,766	144,599	303,639	920,369
	1,215,002	1,506,934	1,735,530	1,006,292	2,049,792	6,933,731
Domestic production	256,050	187,689	254,328	285,368	417,273	914,748
	1,471,852	1,694,623	1,989,858	1,291,660	2,467,065	7,848,479
Per cent represented by domestic production	17.5	11.1	12.8	22.1	16.9	11.7

[a] From records of the Department of Commerce.

During 1914 and 1915 the imports from Ceylon were less than normal, owing chiefly to the high freight rates and scarcity of ships. The sharp increase in the value of the Ceylon graphite imported in 1916 is due largely to the fact that because of the conditions menioned only the higher-grade material was imported.

Domestic flake graphite of a grade suitable for crucible use has increased greatly in price during the last two years. The prices paid at the mines for the highest-grade product, in cents a pound, have been as follows: 1911 and 1912, 6 to 7; 1913, 6 to 8; 1914, 6½ to 8; 1915, 7 to 10; 1916, 10 to 16.

Average prices of crystalline graphite of all grades, including dust as well as flake, have been as follows:

Prices of crystalline graphite, 1911–1916, in cents a pound.

	Ceylon.	Domestic.		Ceylon.	Domestic.
1911	4.3	5.3	1914	4.5	5.5
1912	4.1	5.3	1915	6.4	5.9
1913	4.9	5.0	1916	12.0	8.4

DOMESTIC SUPPLIES.

In the United States crystalline graphite is mined in Alabama, California, Montana, New York, Pennsylvania, and Texas, and deposits are known in Alaska, Maine, Massachusetts, New Hampshire, New Jersey, North Carolina, Vermont, Virginia, and Washington.

Alabama.—The Alabama mines contribute about half the total domestic output. The graphite is found in lenses of graphitic schist, which occur in a broad belt stretching southwestward across Clay, Coosa, and Chilton counties. Where mined the schist contains an average of about 3 or 4 per cent of graphitic carbon. The deposits are weathered to depths of 50 to 65 feet, and mining is confined to the weathered material. Weathering has lessened the coherence between the graphite and other minerals, and consequently the material is more easily mined and milled than unweathered material. The unweathered graphite schist, the "blue rock" of the miners, may eventually be worked, but its treatment will probably involve added expense and some modifications of the present methods of milling. Should conditions arise that would compel the United States to depend on its own supplies of graphite, this "blue rock" may become a valuable resource.

During 1916 seven companies mined graphite in Alabama, three of which were new producers; several more companies have begun operations since January 1, 1917, and others are planning to start in the near future. Mining and milling methods have been much improved in recent years, and costs have been so far reduced that it will be possible for the more efficiently managed companies to continue in operation even under peace conditions. Recent articles by Prouty [1] give interesting descriptions of the Alabama deposits.

New York.—Nearly all the New York deposits of graphite that have been worked are in the eastern and southeastern Adirondack region, in Essex, Warren, and Saratoga counties and the northern part of Washington County. West of the Adirondacks some prospecting and development work has been done in St. Lawrence County. The graphite occurs as disseminated flakes in metamorphic rocks, crystalline limestone, schist, and gneiss, and the graphite content of the material mined averages rather higher than in the Alabama deposits. The deep zone of soft weathered rock which favors cheap mining of the Alabama deposits is, however, lacking in this northern region. Near Ticonderoga graphite also occurs in small veins.

Pennsylvania.—Chester County has for many years been the center of the graphite industry of Pennsylvania and within the last 10 years

[1] Prouty, W. F., Flake graphite in Alabama; its location, its history, and its value to the State: Birmingham Age-Herald, Jan. 28, 1917; Extent and development of flake graphiter esources of Alabama: Manufacturers' Record, Apr. 19, 1917, pp. 66-67.

has been the sole productive district in the State. The rocks mined for graphite are graphitic quartz-mica schists and minor amounts of graphitic limestone. The graphite deposits of Pennsylvania have been described in a special report by Miller.[1] This report may be procured by addressing Richard R. Hice, State geologist, Beaver, Pa., and to it the reader is referred for fuller details.

Texas.—The graphite deposits of Texas are similar to those of Alabama and occur in the vicinity of Burnet and Llano, in the central part of the State. The year 1916 marks the beginning of the Texas production.

California.—Deposits of graphitic schist have been mined in southern California, in Los Angeles and San Diego counties. These deposits resemble the characteristic deposits of New York, Pennsylvania, and Alabama in that the graphite occurs as flakes disseminated through a schist. The flakes in the California schists, however, are much smaller than those in the eastern deposits, most of them not exceeding 0.25 millimeter in diameter, and therefore the material is not adapted for use in the manufacture of crucibles. On the other hand, the percentage of graphite in the California deposits appears to be nearly twice that of most of the eastern deposits of similar type.[2]

Montana.—A deposit of crystalline graphite is being mined near Dillon, Mont., and is of particular interest because the graphite occurs in veins, like that of the Ceylon deposits. One mine has reached the producing stage and has made shipments to the eastern markets.

Nonproductive areas.—Extensive deposits of graphite-bearing schists occur in Alaska on both the northern and southern slopes of the Kigluaik Mountains, in the southern part of Seward Peninsula. Two companies are developing these deposits but have not yet produced commercial quantities.

Some development work has been done recently on graphite properties on the eastern slope of the Cascade Range in Chelan County, Wash.

Graphite occurs in many places in the crystalline rocks of the Atlantic States but except in New York, Pennsylvania, and Alabama has not been mined successfully. It is present at several localities in Maine,[3] and in 1905 an unsuccessful attempt was made to mine it near Madrid, in Franklin County. Graphite also occurs in the crystalline rocks at many places in Vermont and New Hampshire but has never been successfully mined. In Massachusetts a graphite deposit near Sturbridge, not far from the Connecticut boundary, was worked as early as 1658, and the mine is therefore one of the oldest

---

[1] Miller, B. L., Graphite deposits of Pennsylvania: Pennsylvania Top. and Geol. Survey Comm. Rept. 6, 1912.

[2] U. S. Geol. Survey Mineral Resources 1915, pt. 2, p. 87, 1916.

[3] Smith, G. O., Graphite in Maine: U. S. Geol. Survey Bull. 285, pp. 480–483, 1906.

in the United States. Little work has been done here in recent years, however.

Graphite is found in disseminated flakes in the crystalline rocks of the highlands of northern New Jersey at a number of localities. Several attempts to mine and concentrate the material have been made in the past but have not proved successful, and the State is not now a graphite producer.

Although graphite is not now produced in Virginia it occurs at a number of localities in the Piedmont region, east of the Blue Ridge. Some development work was done in 1915 in the northern part of Albemarle County.

Graphite has been found at many places within the area of crystalline rocks in the central and western parts of North Carolina. The principal graphite deposits of this State have been briefly described by Pratt,[1] and copies of his report may be obtained from the State geologist, Chapel Hill, N. C.

PROSPECTS OF INCREASING THE DOMESTIC OUTPUT.

From the short descriptions given above it will be seen that the United States possesses a considerable reserve of crystalline graphite, for the most part suitable for crucible manufacture. At the ordinary price of graphite, however, it is possible to mine only the most favorably situated deposits. Cheap labor and large and easily mined deposits make mining costs in Ceylon much lower than in America and offset the freight charges.

The graphitic schists from which American flake graphite is derived require crushing and concentration. The developing of milling methods especially adapted to the treatment of graphite has not yet reached any degree of standardization, and the quantity saved is rarely over 60 per cent of the graphite content of the ore. Recenc important developments have been the adaptation of electrostatit separation to graphite concentration and the use of oil flotation. Each improvement in graphite treatment results in a larger proportion of clean concentrates of the best grades. Continued improvement in methods of treatment will probably result in a better situation for American flake graphite after the war. Many manufacturers who before the war used imported graphite exclusively have perforce turned to the American product and, finding the graphite of the better grades suitable for their purposes, have used it mixed with Ceylon graphite, and they will continue to use it unless Ceylon graphite of good grade can be put on the market at greatly reduced prices. It can not be expected, however, that the present prices of flake graphite will continue after the war, for there will be no longer the

[1] Pratt, J. H., The mining industry in North Carolina during 1901: North Carolina Geol. Survey Econ. Paper 6, pp. 69-72, 1902.

tremendous demand for graphite as an adjunct to munition manufacture, and graphite from Ceylon and other foreign countries will again enter the market under normal conditions. Those contemplating the development of graphite deposits should estimate the probable costs very carefully and be sure that the deposit is one that shows good promise of being profitably mined at normal prices.

AMORPHOUS GRAPHITE.

Amorphous graphite is suitable for all purposes for which graphite is used except the manufacture of crucibles. As it does not enter to any large degree into the manufacture of munitions, the war has not greatly affected either price or production. Moreover, artificial graphite and crystalline graphite in particles too small for crucible manufacture are adapted to practically all uses to which natural amorphous graphite can be put, and the reserves of amorphous graphite are therefore less important. The uses of amorphous graphite vary greatly with the purity of the substance mined. For paint and foundry facings a high degree of purity is not essential, but for lubricants, pencils, and electric purposes high-grade material is necessary. The better grades of amorphous graphite are imported from Mexico and Chosen, and the imports, like those of crystalline graphite, greatly exceed the domestic output. The sharp decrease in importation in 1915 shown in the following table was due chiefly to the disturbed conditions in Mexico, but also to decreased imports from Chosen owing to high freight rates and scarcity of ships.

Amorphous graphite imported and produced in the United States, 1911–1916.

Quantity (short tons).

	1911	1912	1913	1914	1915	1916
Imports	5,199	6,031	9,501	10,917	4,080	10,837
Domestic production	1,223	2,063	2,243	1,725	1,181	2,622
Total available supply	6,422	8,094	11,744	12,642	5,261	13,458
Per cent represented by domestic production	19.0	25.6	19.1	13.6	21.9	19.5

Value.

	1911	1912	1913	1914	1915	1916
Imports	$279,927	$202,403	$270,217	$290,969	$111,286	$345,732
Domestic production	32,415	32,894	39,428	38,750	12,358	20,723
Total	312,342	235,297	309,645	329,719	123,644	366,455
Per cent represented by domestic production	10.4	14.0	12.7	11.8	10.0	5.7

ARTIFICIAL GRAPHITE.

Graphite in large quantities is manufactured at Niagara Falls, N. Y., by the International Acheson Graphite Co., which utilizes electric power generated at the Falls. The bulk graphite produced by this company in 1915 was reported as 2,542 short tons, and in 1916 as 4,199 tons. This represents only the graphite that would come into competition with natural graphite and does not include graphitized products that do not compete with natural graphite. The material, most of which is made either from anthracite or from petroleum coke, comes from the furnace in an earthy, incoherent condition and is utilized mainly in lubricants and paints and for foundry facings, boiler-scale preventives, and battery fillers.

Besides the graphite products that enter into competition with natural graphite, there are a large number of graphite products for which artificial graphite is especially adapted. Chief among these are graphite electrodes, the demand for which has greatly increased during the last two years on account of the remarkable growth in certain electrochemical industries. The extent of this growth is indicated by the statement[1] that during 1915 the number of electric steel furnaces in operation in this country increased 78 per cent.

POSSIBLE INCREASE OF SUPPLY.

The domestic production of amorphous graphite is of minor importance both in amount and grade compared to the imports, and an expansion of the artificial graphite industry could supply any demand for this material. An increase in the production of crystalline graphite, however, is very important. This may be accomplished by bringing new areas into active production and by increasing the efficiency of milling operations. Increased efficiency would in turn make it profitable to mine deposits now considered unworkable. At present in Alabama, where the deposits are cheaply mined, material containing 3 per cent of graphite by weight is the poorest that can be successfully mined. The problem of concentrating the lightest material in an ore, rather than the heaviest, is one that demands further intensive study. Many of the graphite deposits of the present non-productive areas might be mined if processes of treatment could be improved, and further study of these deposits would determine which district shows the best promise of future development. Prospecting is proceeding vigorously but is largely confined to areas in the neighborhood of the present productive mines.

[1] Iron Age, Jan. 6, 1916, p. 95.

COAL.

By C. E. Lesher.

PRESENT CONDITIONS.

It is perhaps difficult for many to understand why, in view of the facts that nearly 600,000,000 tons of coal was mined and used last year and an unlimited supply is yet unmined, there should have been any trouble in getting fuel in the winter of 1916–17, or to believe that there may be trouble again next winter. A public fully informed on this matter and ready to cooperate in preventive measures will be the best means of averting serious conditions later.

Those who have been keeping in touch with conditions in the bituminous-coal industry foresaw and forecast the recent great increase in prices months ahead, but no one was so bold a year ago as to predict that in the near future prices would reach and stay at so high a level. These high prices, in conjunction with a serious shortage of coal at consuming centers, turned the thoughts of users throughout the United States to the subject of fuel and furnished a motive for many investigations, Federal, State, and municipal.

What has happened to the coal industry since the European war began is intimately and intricately tied up with the extraordinary things that have happened to all machinery of domestic production, including labor and transportation, and all these things are in one way or another related to the great war. The consumer in the United States has not had to confront the cutting off of imports of coal, for this country, above all, is self-contained in its coal supply and imports but trivial amounts. The warring nations in Europe have not called for coal as they have for foodstuffs and metal products, and coal exports to neutral countries—for instance, to South America—although increasing somewhat, have fallen far below expectations in 1914. Exports of bituminous coal were but 1,100,000 net tons greater in 1916 than in 1913, an increase of 5 per cent, and the total exports represented only 4 per cent of the production in 1916.

WHERE THE COAL GOES.

Any attempt to review the conditions that have resulted in so large an increase in output and at the same time such high prices must take account first of the larger uses for which bituminous coal is mined. The United States Geological Survey has shown that the railroads in 1915 used 122,000,000 tons of bituminous coal and 6,000,000 tons of anthracite, or 24 per cent of the combined total production; the coke ovens required nearly 62,000,000 tons of bituminous coal; and manufacturing and power plants burned approximately 180,000,000 tons of bituminous coal and anthracite, or about 28 per cent of the output. The stimulation of any of these industries at any time increases the demand for coal; intense activity in transportation, iron business, and general manufacturing, such as began in 1915 and continues to-day, inevitably results in great activity in the coal market. A direct measure of this activity is afforded by the figures indicating production. The output of bituminous coal in the United States in 1914 was 422,000,000 tons. In 1915 it was 442,000,000 tons, an increase of 20,000,000 tons, and the output in 1916 is estimated at 509,000,000 tons, or 67,000,000 tons more than in 1915. This increase has been largely taken by the railroads, the coke ovens, and the manufacturing plants. The production of anthracite, about 88,000,000 net tons in 1916, has not varied greatly in recent years.

The quantity of coal for locomotive fuel required to move this additional output to market was in itself, of course, no inconsiderable item, and the extraordinary movement of other heavy freight to both seaboards in 1915 and 1916 called for a larger amount of engine fuel than was ever before needed. The quantity used by locomotives in 1916 exceeded that used in 1915 by 13,200,000 tons of bituminous coal and 400,000 tons of anthracite, an increase of 10 per cent.

The activity of the iron and steel business in 1915 and 1916, due largely to the over-sea demand for our products, stimulated coke production, and in 1916 the output of coke broke all records.

To produce a ton of pig iron from the ore requires an almost equal weight of coke, or about 1½ tons of coal, and to convert the pig iron to steel and then to fabricate the steel into the form in which the greater part of it is exported requires still more fuel. The quantity of bituminous coal mined in 1916 for export directly as coal and coke and indirectly as iron and steel products was around 40,000,000 net tons. From this it is seen that the increase in output of bituminous coal has been in large measure due to the stimulus of foreign war markets for the products of the United States.

NO STORAGE AT THE SOFT COAL MINES.

The producers of Pennsylvania anthracite are able to equalize production somewhat throughout periods of unequal demand by storing a part of their coal; except at the head of the Great Lakes the producers of bituminous coal have no storage facilities. Bituminous coal must therefore be marketed as soon as it is mined, and it is mined only as there is demand for it and as facilities are available for transporting it to market. The need or demand, then, sets a practical limit on production. For instance, in the summer the consumers of bituminous coal have minimum requirements and times are dull about the mines. In winter their requirements for fuel reach a maximum, the railroads, industrial plants, and public utilities all contributing to increase the load on the producers.

SCARCITY OF MEN AND CARS CAUSES SHORTAGE OF COAL.

That the shortage of coal in the winter of 1916-17 was not due to lack of coal in the ground nor to scarcity of mines, but to shortage of labor and insufficient transportation facilities has previously been pointed out by the Geological Survey.

The capacity of the equipped and developed bituminous coal mines in the United States is sufficient to furnish more coal than has ever been demanded and the opening and improvement of new mines is more than keeping pace with the needs of the country. To mine the coal requires an industrial army (734,000 men in 1915) and a shortage of labor involves an immediate reduction in the output of coal. The greater part of the coal (and beehive coke) produced must be transported considerable distances to reach the consumers. Any failure of the railroads to supply sufficient cars to the mines for loading or to move the loads promptly to their destination checks the production and consumption of coal.

The shortage of labor and the lack of adequate railroad service are recognized as prime causes of the coal shortage, and the reasons for these difficulties are now pretty well understood. Decreased immigration, exodus of foreign-born labor, and rapid expansion of the manufacturing industries that supply all manner of products for home consumption as well as to the warring nations, which called for greater numbers of all classes of skilled and unskilled laborers and offered them high wages, were factors that if not actually reducing the number of men employed in mining coal and in railroading certainly prevented such increases in the number of workers as the greater demands of these industries required. The lack of men has perhaps affected the production of anthracite more than the shortage of cars, but the opposite is true of bituminous coal.

The railroads failed to deliver the service asked of them in the fall and winter of 1916. Their failure in this period and to a less extent earlier in the year, as well as in the fall of 1915, has been a matter of grave concern to the country. The circumstances and conditions that in combination almost paralyzed rail transportation were many, varied, and complex; the events are still too recent to warrant conclusions as to the responsibility. Had the supply of cars been unlimited, there would have been a shortage of locomotives; had the railroads been able to furnish and move all the cars for which there was an apparent demand, yards, switches, and even main-line tracks would have become congested. In other words, the railroads were not prepared to handle the unprecedented quantity of freight the industries were offering.

There is more to the transportation problem than moving freight from origin to destination with dispatch. Shipper and receiver of goods both play important parts. When shippers were sending trainloads of goods to the seaboard with no prospect of ships to receive them, when manufacturers were receiving carloads of coal for which they had no storage room, and when dealers, jobbers, and speculators were using cars for warehouses, they were contributing to the general confusion and helping to accentuate the shortage of cars.

SHORTAGE NEXT WINTER FEARED.

Nothing is more certain than that the country will, next winter, witness a shortage of coal perhaps more serious than in the winter just passed unless unusual efforts are made between now and next fall to prevent it. This is the opinion of the Geological Survey, shared by other competent observers. The entrance of the United States into the war has keyed all industries to a still higher pitch and has put this country on her mettle to outdo the remarkable record of the last 18 months in the production of the implements and accessories of war and in the export of goods and foodstuffs to Europe. The need of coal and coke to run the manufacturing plants and iron furnaces will be no less in the next 12 months than in the last, and probably will be even greater. The greatly increased activities of our naval forces means larger coal consumption, and the demands on the railroads for the transportation of troops and supplies will also increase the use of coal for railroad fuel.

The mines that must meet this extra demand for coal will have fewer men, for some will join the military and naval forces or go to other industries for higher wages. The railroads that move the coal from mine to consumer will have fewer men and but few additional cars and locomotives. The shortage of coal last winter was serious, even though the operators, spurred on by high prices, were putting forth every effort to meet the demand. The combined efforts of the Interstate Commerce Commission and the railroad managers did not suffice to relieve the car shortage, and at times they found it necessary to clear the tracks and give coal the right of way to keep such cities as Chicago from a fuel famine.

With the price of coal at a higher level than ever before, the coal-mine operator may be counted on to do his utmost to meet the demand, but he can do only as much as the men at his command can do for him. On the days when no railroad cars are pushed under his tipple his mine must be idle, for he has no way to store coal, once mined. With the experience of the last six or seven months behind them, the officials of the railroads are fully alive to the situation and will be better able, next winter, to handle the problem of getting the empties to the mines and the loads to market, but with no great increase in equipment and motive power, possibly with fewer men, and certainly with more freight to handle, there is little hope that they can effect sufficient improvement in distribution to prevent congestion during the coming winter.

APPEAL TO THE CONSUMERS OF COAL.

The consumers of coal are those who suffer most when there is a shortage of fuel and prices mount to high levels. The producing and transporting ends of the business are ready and willing to do their utmost to help and yet are unable to accomplish all that is necessary; it is the duty of the consumer to lend his aid. The demand for coal is seasonal—greatest in the winter and least in the summer. It has repeatedly been shown that if some way were devised to equalize this demand, the difficulties in furnishing coal would be reduced to a minimum. Had the comparatively few million tons of coal the unsatisfied demand for which caused panic prices last winter been ordered during the preceding summer the mines could have produced it and the railroads moved it without difficulty, and much of the trouble would have been averted. The remedy is simple and well known to all familiar with the industry—coal must be stored in the summer in excess of summer requirements and at the point of consumption.

The largest individual consumers of coal are the railroads and the industrial plants. Many of these consumers have learned the necessity of storing coal and realize that in the end the cost is more than repaid. Some of the railroads have had at different times several hundred thousand tons of bituminous coal in stock piles along their routes, and the Pennsylvania System is reported to have had at times a reserve of a million tons or more. The railroads used up nearly all their stored coal last winter, but they are already beginning again to accumulate a stock. By the time snow flies, millions of tons of soft coal will be in their storage piles.

Many of the manufacturing plants and other industrial works have storage facilities, but in general these plants, particularly the smaller ones, have no storage space or means of taking care of any but current fuel requirements. They have not in the past prepared to store coal, because they were under no necessity for doing so, but it is evident that they should prepare now. Should one-half of the larger users of steam and gas coal—that is, the industrial and public-utility companies—uniformly throughout the country have on hand by November 1 a three months' supply of coal, a big load will be taken off the railroads next winter and the coal situation will be less strenuous. It is physically impossible for many concerns to store any such quantity of coal on their premises, but every consumer should do his utmost.

Small consumers, mainly households, hotels, and schools, use annually about 100,000,000 tons of bituminous coal and anthracite, a large part of which is distributed by the city and town retail dealers. Every extra ton these dealers store this summer will help relieve the tension next winter; every ton the householder puts in his cellar before October will help the country. The proof of this statement is found in the experience of the Pennsylvania anthracite operators, who since 1902 have offered reductions in price on the domestic sizes during the summer and have thus encouraged and educated the householder and others to store all or part of their winter's supply of fuel. The result has been that the shipments of anthracite from the mines in the summer are nearly as great as in the winter.

No one should hesitate to store coal now in the belief that the price will fall next winter. It is the present disposition of the sellers of soft coal to contract or otherwise obligate themselves to deliver no more than half of their expected output in the next 12 months, whereas in the year just closed their contracts covered more than three-fourths of their expected output. The operators have taken this stand partly because of the uncertainty as to the quantity they will be able to deliver, but doubtless largely because they expect the market prices of coal to be high and they wish to have sufficient tonnage free so that they can share in these high prices. Because of the falling off in demand, the wholesale price of bituminous coal usually drops in the summer, but if the consumers buy larger quantities than ordinarily for storage, prices will not drop as much as usual during the summer, and with the winter demand lessened to the extent to which surplus coal was stored in the summer the price next winter will not rise to so high a level. In other words, production and prices will be somewhat equalized.

The larger anthracite operators have recently offered the usual April reduction of 50 cents a ton on the prepared sizes, and a reduction of 10 cents less each month until the fall and winter price is reached in September.

All users of coal should take full advantage of the summer prices. It will pay them to store coal now, whether they use bituminous or anthracite.

Uniform working time at the mines and uniform prices for coal throughout the year represent the millenium toward which the coal-mine operator, the shipper, and the responsible retail dealer have been looking. It is confidently expected that those engaged in the coal trade will give every aid and assistance to their customers and to the country in general in endeavoring to avert next winter a repetition of the coal shortage just experienced. The producer of coal will evidently profit more if he ships steadily throughout the summer than if the price later reaches unheard-of figures and he can not get his product to market.

The appeal to the consumer that he buy and store coal against the needs of next winter, and thereby personally save trouble and expense, may appear a strange call to patriotic duty, but when every consumer of coal realizes that every car of coal unloaded this summer for use next winter will release a car for other important and, perhaps, imperative needs at a time when the need is greatest, there will be no question of the wisdom of the call.

POTASH.

By Hoyt S. Gale.

The greater part of the potash consumed in this country is used as fertilizer. Of the elements essential to plant growth potassium is one of the three or four that ordinarily become deficient or exhausted in cultivated soils. Its use under proper conditions has a stimulating effect on plant growth, and for certain crops a special application of it has come to be regarded as almost essential, as is illustrated by the present demand, even at abnormally high prices, for potash for agricultural use. Much of the present small output in this country is being used in fertilizers, and the need of potash for particular crops is indicated by the fact that the scarcity and demand in the United States have not prevented considerable shipments of our own product to Cuba for agricultural use, presumably for tobacco.

The need of potash in certain industries is acute. It is essential in the manufacture of the best liquid soap and some higher-grade cake soaps and of some finer grades of glass. It is absolutely necessary in the manufacture of certain explosives, although the great bulk of modern explosives are made without potash. Potash now enters largely into the manufacture of matches. The several potash salts find many particular uses in industries so varied as tanning, dyeing, metallurgy, electroplating, and photography. They are also used in medicine and for miscellaneous chemical purposes. On the whole, the chemical requirements, though minor as regards actual quantities consumed, are the most urgent of the demands for potash and in case of an abnormal restriction of the supply are the first to be provided for.

The output of potash salts and potash products in the United States during 1916 has been reported to the amount of 35,739 short tons, having a mean potash content of about 27 per cent K_2O and a total potash content of 9,720 short tons of K_2O. This is almost exactly 10 times the production reported for 1915, although it is still perhaps less than 5 per cent of the normal potash consumption. In 1913 the only potash known to have been produced within this country was made from wood ashes.

Practically all the possibilities predicted in the many recent publications of the United States Geological Survey discussing potash sources found some fulfillment in the production of 1916. The almost entire stoppage of supplies from abroad and the meager stocks on hand with which to meet the requirements have at times carried the price of potash from a normal figure of 50 to 75 cents to $5 or $6 a unit (1 per cent of potash per ton of material).

The forms in which potash has been produced and marketed are so diverse that it is difficult to make a summation of actual tonnage that will have any real significance. Therefore the tonnage reports of all forms have been reduced to terms of available or water-soluble potash (K_2O) contained in the product, which is the standard commercial unit by which the potash value of these materials is usually expressed.

Summary of potash production in 1916.

Source.	Available potash (K_2O) (short tons).	Value at point of shipment.
Natural salts or brines	3,994	$1,937,600
Alunite and silicate rocks, including recoveries through furnace dust	1,850	715,000
Kelp	1,556	781,100
Wood ashes (potashes, pearlash)	412	270,000
Distillery waste (molasses)	1,845	500,900
Miscellaneous organic sources	63	38,130
	9,720	4,242,730

The foregoing list does not include many fertilizer materials previously on the market, such as cottonseed meal and tobacco stems, some of which are largely or chiefly valued for their potash content and whose price has accordingly risen in the present market. These materials, being by-products of other industries, are not produced primarily because of their content of potash. The total given therefore represents the marketed production of potash salts and products manufactured especially or chiefly for their potash value.

The largest output of potash has come from the alkali lakes in western Nebraska, which have afforded the most readily available supply of moderately high grade potash salts, obtained by direct drying of the raw material with perhaps as few technical complications as could be involved in any chemical operation. The great deposit at Searles Lake, Cal., is only just being brought to the producing stage, the enterprise having suffered many reverses, technical and otherwise. The production of potash from alunite has been fairly regular, without much expansion. Some progress has been made in extracting potash from silicate rocks, at least one plant having successfully produced glassmaker's potassium carbonate from greensand. Some feldspar has been mined, ground, and so treated that a small percentage of its potash was rendered soluble and thus available for use in fertilizers, but no account of this material is included in the figures for 1916, as little of it was marketed within that year. So far as has been ascertained none of the leucite, mica schist, sericite schist, or similar rocks high in potash have yet yielded any commercial quantity of water-soluble salts.

The production of potash from organic materials has been attempted in various forms. Much publicity has been given to the efforts to obtain potash and potash fertilizers from kelp, and a great deal of development work has been done in that connection. The manufacture of high-grade potash fertilizer salts from molasses distillery waste has also been developed and bids fair to be a permanent industry; in 1916 the output so obtained exceeded the production from kelp. The manufacture of potash from wood ashes by the old-time methods continues with a small but significant contribution to the total tonnage.

It must be recognized that much if not most of the present production of potash is maintained on the basis of war prices, and there is no doubt that a large part of it can not be continued after these prices drop. Some of the developments have promise of permanence, but unfortunately these are as yet on a small scale. The only exception, perhaps, is the Searles Lake project, which now bids fair to yield enough potash to take the edge off the market by supplying the absolute necessities for home consumption in the chemical industries, but this project is as yet hardly under way. So far as can now be predicted there is no domestic source adequate to supply more than a small percentage of the domestic consumption. This statement does not by any means preclude all hope of future success.

The activity of private initiative in the search for sources of potash is increasing. Some very wide fields in the possibility of recovering potash as a by-product—for example, from cement-mill and blast-furnace flue dusts—are now being opened. Although the prospects seem bright for some of these attempts, it can not be said that knowledge has proceeded far enough to insure success on the extensive scale needed to make the country independent of foreign supplies. Perhaps, too, the real hope for a solution of the problem lies in the possibility of discovering, in association with some of the very extensive and little-known domestic deposits of rock salt, a supply of potash that may compete with the foreign sources on equal terms. Valuable potash deposits exist in the Permian in central Germany, the Oligocene (Tertiary) in Alsace, the lower Miocene (Tertiary) in Galicia, the supposed Eocene or Oligocene (Tertiary) in northeastern Spain, and beds of undetermined geologic age in India—everywhere in conjunction with deposits of common salt, dolomite, and gypsum—and it would be strange if occurrences of this sort were confined entirely to the salt deposits of Europe and Asia.

Governmental agencies have served and are still serving a useful purpose in aiding development. They have led the search for possible sources of raw materials of all kinds. By publicity they have stimulated a healthy interest which has undoubtedly led to good results.

As is well known, practically all the potash normally used in this country has formerly come from Germany. In addition to the potash materials used as ingredients of fertilizers, such as kainite and manure salts, almost the entire supply of the basic salts potassium chloride (muriate) and potassium sulphate was received direct from German ports until 1914, a small amount finding its way through Belgium and the Netherlands. In 1914 this importation was greatly reduced, and at the end of January, 1915, it was practically ended by the promulgation of an embargo on the export of potash from Germany. The large imports from Germany during 1915 were doubtless composed of shipments made during January, before the embargo went into effect, and of cargoes gathered up on the way or taken from storage in other parts of the world. Odd lots of potash came late in 1915 from many sources in Europe, North and South America, and even from Asia and Africa. The same condition prevailed in 1916, except that the imports from Germany were entirely shut off, and odd lots seem to have been derived from still more remote sources.

The present situation of this country concerning potash, with a view to possible emergency requirements, though not ominous, requires most careful consideration. It may be assumed that the stocks of high-grade salts of German origin remaining in the United States and, indeed, throughout the world except in the central allied countries are now practically exhausted. The actual domestic production of high-grade salts, moreover, is still very small and is limited to a very few sources, and the difficulties in the way of refining the large bulk of low-grade potash materials would probably be great.

BAUXITE AND ALUMINUM.

By James M. Hill.

USES.

Bauxite, the ore of the widely useful metal aluminum, has also an important use in the manufacture of artificial abrasives, which are of wide application in all metal industries, at present particularly in the finishing of guns, cartridge cases, and motor parts. Bauxite is also the basis of an extensive chemical industry, being the crude material from which alum, aluminum sulphate, and several other chemicals used particularly in water purification, dyeing, and tanning are made. Owing to the greatly enhanced price of aluminum sulphate, several municipal and industrial waterworks have recently installed small plants to make it for use in purifying their water supplies. A use for bauxite that is expanding at a rapid rate is in the manufacture of bauxite brick, more properly called, according to the United States Geological Survey, high-alumina refractories. For furnace linings, these refractories are reported to be replacing the more expensive magnesite and other refractory materials.

The uses of aluminum are myriad, but as some are more essential than others, it is likely that the minor articles formerly made from aluminum will for the present be made in smaller quantity, because the available supply of aluminum will probably be diverted to more urgent uses.

PRODUCTION.

In statistics for years prior to 1916 published by the United States Geological Survey the output of aluminum abrasives has been included with that of other artificial abrasives and can not now be separated, but the domestic production in 1916 amounted to 30,708 short tons, having a value of $2,139,230. The following table shows the steady growth of the industries that consume the greater part of the crude bauxite produced in the United States. No figures are available concerning the quantity of high-alumina refractories manufactured.

Bauxite products in the United States, 1905–1916.

Year.	Unmanufactured aluminum consumed (pounds).	Aluminum salts produced.				Imports.[a]	
		Alum.		Aluminum sulphate.			
		Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
1905	11,347,000	10,114	$289,716	93,917	$1,660,515	1,282	$26,242
1906	14,910,000	15,613	450,125	89,246	1,613,050	1,183	23,193
1907	17,211,000	10,404	361,900	106,821	2,008,046	1,562	35,191
1908	11,152,000	7,700	236,710	97,255	1,835,213	1,407	24,929
1909	34,210,000	9,237	295,682	115,366	2,214,122	1,459	29,061
1910	47,734,000	9,090	300,763	126,792	2,447,552	2,127	53,671
1911	46,125,000	10,468	329,686	134,077	2,743,336	2,283	56,833
1912	65,607,000	9,246	293,995	150,427	2,909,495	3,342	84,606
1913	72,379,000	9,605	312,822	157,749	2,977,708	2,702	66,549
1914	79,129,000	18,238	565,989	164,954	2,942,572	2,891	73,028
1915	99,806,000	24,915	699,256	169,153	3,224,495	1,408	34,320
1916	123,708,000	27,257	1,177,881	153,860	4,410,741	1,247	68,660

[a] Includes alumina, aluminum hydrate, or refined bauxite, alum, alum cake, aluminum sulphate, aluminous cake, and alum in crystals or ground.

The growth of the American aluminum industry has been steady heretofore, but it is probable that the production in 1917 will show a pronounced increase, owing to the operation of the new plant at Badin, N. C., which is practically completed and which made a small output in 1916. This project, started by French capital,[1] was taken over by American interests in 1915 and pushed to completion.

CONSUMPTION.

The consumption of bauxite in the United States has increased steadily because of increase both in the consumption of aluminum and in the output of other products made from bauxite. It is particularly gratifying to know that although the consumption of bauxite in the United States in 1916 amounted to 425,130 long tons, an increase of 41 per cent over the consumption in 1915 and of 74 per cent over the consumption in 1914, practically all domestic requirements were met by the American producers. This bears out the forecast made by the Geological Survey in 1914,[2] that the domestic deposits would be more actively developed to supply the demand formerly met by French bauxite.

[1] Smith, G. O., Our mineral reserves: U. S. Geol. Survey Bull. 599, p. 26, 1914.
[2] Idem, p. 27.

Bauxite consumed in the United States, 1905-1916.

Year.	Domestic production.		Total value.	Imports.		Consumption.	
	Georgia and Alabama (long tons).	Arkansas and Tennessee (long tons).		Quantity (long tons).	Value.	Quantity (long tons).	Value.
1905	15,173	32,956	$240,292	11,726	$46,517	59,855	$286,809
1906	25,065	50,267	368,311	17,809	63,221	93,141	431,532
1907	34,271	63,505	480,330	25,066	93,208	122,842	573,538
1908	14,464	37,703	263,968	21,679	87,823	73,846	351,791
1909	22,227	106,874	679,447	18,688	83,956	147,789	763,403
1910	33,096	115,836	716,258	15,669	65,743	164,601	782,001
1911	30,170	125,448	750,649	43,222	164,301	198,840	914,950
1912	33,760	126,105	768,932	26,214	95,431	186,079	864,363
1913	27,409	182,832	997,698	21,456	85,746	231,697	1,083,444
1914	18,547	200,771	1,069,194	24,844	96,500	244,162	1,165,694
1915	25,008	272,033	1,514,834	3,420	17,107	300,461	1,531,941
1916	46,151	378,949	2,296,400	30	87	425,130	2,296,487

BAUXITE DEPOSITS OF THE UNITED STATES.

Deposits of bauxite in Pulaski and Saline counties, Ark., have yielded the larger part of the domestic output. The deposits in the bauxite field of northern Georgia and Alabama have contributed a considerable quantity, and in recent years the fields in central Georgia and Tennessee have made additions to the output.

Bauxite was first mined from the Georgia-Alabama field in 1889, and the Arkansas deposits were discovered in 1891 but apparently were not extensively developed till 1899. Small deposits of bauxite are known in southwestern New Mexico and Texas but have not been put on a producing basis. The central Georgia field has been under development since 1907; the fields near Chattanooga, Tenn., since 1906; and the deposits in Carter County, Tenn., since 1912.

The Georgia-Alabama field, centered about Rome and Cave Springs, Ga., and Rock Run and Piedmont, Ala., has been studied geologically, and the location of bauxite bodies in this field can be predicted with a fair degree of certainty. The Arkansas deposits are also well understood, and the reserves in this field have been estimated with considerable exactness. The central Georgia field has been recently studied in detail by the State Geological Survey, and the results of this investigation will soon be published. It is felt that further detailed examination, based on a thorough understanding of the geology of these deposits, which are in all places associated with kaolin deposits of Cretaceous or younger age, will result in greatly increasing the known reserves. The examination should not only include the well-known areas in Wilkinson, Meriwether, and Sumter counties but should be extended along the belt of Cretaceous and Tertiary sediments northeastward into North and South Carolina and westward into Alabama.

OTHER SOURCES OF ALUMINA.

The extent to which alumina will be recovered in the treatment of alunite for potash can not now be predicted. So far as known to the United States Geological Survey, none of the many proposed methods for treating ordinary clays and kaolins to produce aluminum salts have been proved successful on a commercial scale, but this problem may yet be solved.

ALASKA'S MINERAL SUPPLIES.

By Alfred H. Brooks.

INTRODUCTION.

The principal industrial uses of minerals that are now in special demand or that may be in special demand during the war are described in the other papers of this series, which also treat of the reserves of these minerals within the United States proper. It is the purpose of this article to describe the available mineral reserves of Alaska. The Territory is now producing copper, gold, and silver in large quantities and making a smaller output of antimony, tungsten, tin, lead, petroleum, coal, etc. The output of some of these minerals could be increased without great delay. There is a possibility also that platinum, chromite, molybdenite, and other undeveloped mineral deposits known in Alaska may be able to furnish a supply during the present emergency.

For the purpose of the present paper Alaska's mineral reserves may be roughly divided into three groups. One group includes those so inaccessible at the present time as not to form a part of the available supply. This group includes a considerable part of the mineral wealth of the Territory but needs no discussion here. A second group includes the mineral reserves which, though now inaccessible and undeveloped, could be made available by one or two years of preparatory work. This group includes much of the coal and oil and a part of the copper, gold, and other metalliferous deposits. In general, most of the mineral depoists that are far from tidewater fall in this category, though exception must be made of some tributary to the existing railroads. Undeveloped deposits, even though they are located close to the seaboard, also belong to this group in so far as they require extensive mine equipment before productive operations can be begun. The third group, constituting the most available but much the smallest part of Alaska's mineral wealth, includes developed deposits lying on or near established transportation routes. In this group fall not only the deposits on tidewater and railroads but also those in inland districts that are accessible for a part of the year by river transportation.

TRANSPORTATION.

As the availability of Alaska's mineral wealth depends on transportation, a brief consideration of this subject is necessary. The entire Pacific seaboard of the Territory, with the exception of the upper part of Cook Inlet, is accessible to shipping throughout the year. Mineral deposits that lie on the Pacific seaboard can be made available to transportation without great delay. These include the copper deposits of Ketchikan and Prince William Sound and the gold and silver deposits of Juneau and other coastal districts. However, none of Alaska's mineral wealth is available to industry unless shipping is provided and the paths of commerce are kept open.

The lower Copper River basin is accessible by a railroad which skirts the southern margin of the Kotsina-Chitina copper belt. Unfortunately this railroad has no branches and there are but few wagon roads tributary to it. Therefore the utilization of the copper deposits that do not lie close to the line is dependent on construction, some of which would require much time.

The Government railroad extending inland from Seward is at present in two unconnected sections. One leads from Seward to Turnagain Arm, and the other northward from Anchorage to the Matanuska coal field. The port of Anchorage is closed by ice for several months annually. The work of connecting these two sections is under way but can probably not be completed in much less than a year. Therefore the Anchorage section is now available for transportation only during a part of the year.

The conditions in the rest of Alaska are still less favorable to rapid development. Seward Peninsula is accessible to ocean boats from about June to October, and the inland mining districts depend for transportation on the navigation of Yukon and Kuskokwim rivers and their tributaries. These waterways are open to steamers from about June to October. The Fairbanks district is, however, also accessible by wagon roads leading from the Pacific seaboard at Valdez and from the Copper River Railroad at Chitina. In case of emergency some of its minerals could be sledded out during the period of closed navigation. In the winter of 1915–16 considerable tungsten ore (scheelite) was brought out by sleds.

The transportation conditions involve heavy freight charges, and therefore certain minerals—for example, antimony—can be produced and shipped out only during a period of great demand and attendant high prices. The high cost of transportation also makes for high operating cost, which is likewise a controlling factor in production. On the other hand, mining along the Pacific seaboard does not necessarily involve higher operating costs than in the States—in fact, the costs are less than in many mining districts of the Cordilleran region.

In 1916 mining operations in Alaska were much hampered by the lack of shipping. This was especially true of the copper-mining industry. Had there been ships to transport the ore and smelters and refiners to reduce it, the copper output from Ketchikan and Prince William Sound would have been very much larger than it was.

GOLD AND SILVER.

A large increase in Alaska's gold production under present conditions is hardly to be expected. The present high prices affect gold mining more adversely than any other industry, for they involve a relative decrease in the value of the product. The constantly increased cost of equipment, supplies, and labor maintained during the war make gold-mining ventures less attractive to capital than under ordinary conditions. The most promising field for an immediate increased production of gold is in the placer districts. Yet most of these lie far from the coast or in regions difficult of access. Moreover, the great reserves of auriferous gravels on which the future of the industry depends have a low gold tenor, and their profitable exploitation depends on the installation of machinery—a matter that involves much time and capital. Hence, even public-spirited operators who might be willing, for the sake of increasing the gold output, to operate at the lesser profit which war-time conditions involve could hardly bring an enterprise to a productive basis in less than two years. It is not intended by this statement to imply that the production of placer gold will fall off while the present economic conditions prevail, but only to point out that a greatly increased output can hardly be expected. There are, however, a number of large placer-mining plants that have been under construction for a year or more, and some of them may yield gold this year to help swell the total. Moreover, in many Alaska districts there are rich deposits that are being mined by simple methods and will continue, as in the past, to be the source of a large part of Alaska's placer-gold output. In 1916 the value of the placer gold produced in Alaska was $11,140,000; in 1915, $10,480,000. It is not possible to forecast what the output of 1917 will be, but there is no reason to believe that it will materially decline.

The conditions described above as affecting gold-placer mining are still more potent in gold-lode mining. The mining of siliceous auriferous ores had been on the increase for a number of years until 1916. The value of the gold output from this source was $5,912,736 in 1916 and $6,069,023 in 1915. Of the total output in 1916 over $4,500,000 came from the large low-grade mines of the Juneau district. These great enterprises, which depend for their economic success on the handling of a large tonnage at a small margin of profit, will be more directly affected by the present adverse economic conditions than the smaller mines working on ores of high value. The recent serious accident to the great Treadwell group of mines, details of which are lacking at this writing, may reduce the gold output of the Juneau district. It is probable that there will be an increased gold output from the small mines of the Willow Creek and Prince William Sound districts, but this will for the present not be sufficient to offset the decrease in the Juneau output. Therefore the present outlook indicates that the production of lode gold in Alaska will be less in 1917 than it was in 1916.

Alaska's silver output, which in 1916 amounted to 1,379,261 ounces, valued at $907,554, has practically all been won incidentally to the mining of gold and copper. Though the Territory contains some argentiferous galena deposits, referred to below, these are almost undeveloped. Of the silver produced in 1916 over 1,200,000 ounces came from the copper lodes. With the expected increase of copper mining during 1917 the output of silver will also increase.

COPPER.

The increase in the output of copper due to high prices for that metal is the most striking feature of Alaska's recent mining history. In 1914 the copper output from Alaska mines was 21,450,000 pounds; in 1915, 86,500,000 pounds; and in 1916, 119,600,000 pounds. In 1916 eighteen copper mines were operated in Alaska, but much the larger part of the output came from three large mines—two in the Copper River region and one on Prince William Sound. It is unfortunate that the maintenance of a large copper output from the Territory is so greatly dependent on the continued operation of two large and very rich mines in a single district, for if, by any accident to mining or to transportation, operations and shipments from this district should be interrupted, there would be a tremendous curtailment of the annual copper yield. The maintenance of Alaska's copper output is of importance under present conditions, and every encouragement should be given to the development of other deposits, especially those of the Pacific seaboard. A large number of mines, especially on tidewater, would give far greater assurance of a steady production of copper than the present conditions. The small copper producers of Prince William Sound and the Ketchikan district met with most discouraging conditions in 1917. In spite of the high price of copper they were unable to obtain either sufficient transportation for their ore or any assurance that the smelters would handle it if it could be shipped.

The two large mines in the Chitina belt are probably now being worked to the limit of their capacity. The full development of the only other productive mine in this district is hampered by lack of transportation; up to the present time its shipments have been made only in the winter. There are in this general region other properties which, if connected with the Copper River Railroad by aerial trams and spurs, would ship ore. Most of these have not yet been developed sufficiently to reveal any very large tonnage of ore. Any census of Alaska copper reserves that might be made available during the next two years, however, must take these into account. The best hope of an immediate increase of the copper output is in the development of the lodes along the Pacific seaboard. In 1916 there were nine productive copper mines in the Ketchikan district and six on Prince William Sound. In these two districts there are at least a dozen other copper properties which have been sufficiently developed to justify the hope that they could be brought to a productive basis within the present year. These properties, together with the fifteen that made an output in 1916, if developed to their full capacity, would probably increase their output of 1916 by 10,000,000 to 12,000,000 pounds in 1917. Such an increase can be brought about only, first, if copper remains at a high price, and, second, if shipping for transporting the ore and smelters for reducing it are available.

To sum up the copper-mining situation, there is good reason to believe that if the high price is maintained the Alaska copper output in 1917 will be larger than that in 1916. The best hope for an immediate and considerable increase is by providing better shipping and smelting facilities for the mines of the Pacific seaboard. Should the war make larger demands for Alaska copper, it is probable that within two years a still greater increase in the copper output could be brought about by providing means of transportation from such deposits of the Kotsina-Chitina district as are now unproductive.

TIN.

Placer tin has been mined in the York district of Seward Peninsula since 1902. The total tin output of Alaska up to the end of 1916 was 767 tons of metallic tin. This total includes a small output of lode tin from the York district and also some placer tin from the Hot Springs district, in the Tanana Valley. In the Hot Springs district the tin has been won incidentally to the placer mining of gold, and the first shipment of stream tin from this district was made in 1911. Alaska produced 139 tons of metallic tin in 1916 and 102 tons in 1915. The present urgent demand and consequent high price of tin will undoubtedly lead to a greater output in 1917. Most of the tin now produced in the York district is the product of two dredges. There are a number of tin-bearing placers in this field, but even at present prices they can probably not be profitably exploited except by the use of dredges. As it would take a year to install a dredge, there is no hope of making a notable increase this year in the production of placer tin from the York district. There are a number of tin lode prospects in the York district, from two of which some production has been made. In 1917 a mill was installed at one of these mines, and its output should help to swell the tin production during 1917.

The York tin mines are worked only during the summer, and the shipping season is limited from about June to October. The uncertainty of the present means of ocean transportation for this field is shown by the fact that a large percentage of the tin produced there in 1916 failed to reach the market and can not now reach it until midsummer of 1917.

Stream tin is rather widely distributed in the Hot Springs district, but as yet few of the placer miners make any effort to save it. If they could be induced to save and ship their stream tin it might materially increase the total output from the Territory. Placer mining in the Hot Springs district can be carried on for about three months in summer. Transportation is afforded by river, and the open season of navigation is from June to October.

It is probably safe to state that the Alaska tin production of 1916 could be doubled in 1917—that is, it could be brought up to nearly 300 tons of metallic tin. In view of the great need of tin in the United States it is hoped that the Alaska miners will make every effort to increase their output.

TUNGSTEN.

Though scheelite has long been known to occur in the placers of the Fairbanks, Iditarod, and Nome districts, it has only recently been found in lodes. In 1915 a scheelite-bearing lode was opened near Fairbanks, and some shipments of ore were made by parcel post brought to the coast by the winter mail. Other scheelite-bearing deposits were developed in Fairbanks and also in the Nome district during 1916. Meanwhile some of the operators of dredges in the Nome and Iditarod districts began to save scheelite from the concentrates.

Wolframite and scheelite occur in some of the tin ores of the York district, Seward Peninsula, but these deposits have been only slightly developed. Wolframite has also been found in association with some of the gold placers of the Yukon-Tanana region. In 1916 a little wolframite won from the placers was shipped from the Birch Creek district.

In all, about 47 tons of tungsten-bearing mineral concentrates, chiefly scheelite, carrying from 60 to 65 per cent of WO_3, were shipped from Alaska in 1916, about 30 tons of which came from Seward Peninsula. All of this output came from districts that are open to transportation during only a part of the year. The scheelite lode deposits that have been opened could probably double their production in 1917 if high prices are maintained and if there is assurance of a market for the product. To the lode production could be added the scheelite obtained from placer mining, notably from dredging, if operators will save the concentrates. It is probable, therefore, that the summer mining operations of 1917 could be counted on for 130 tons of scheelite concentrates.

ANTIMONY.

Stibnite, as has long been known, is very widely distributed in Alaska, but it is only the stimulation of war prices and demand of the last two years that has caused any of this ore to be mined. In 1915 the output of stibnite ore was 833 tons; in 1916 it was 1,458 tons. Most of this ore came from the Fairbanks district, where half a dozen mines have been developed on a small scale. Some ore has also been shipped from two mines in the Nome district. Transportation from both these districts is limited to the open season.

The most accessible of Alaska's antimony lodes is one located in the Ketchikan district, where a little development work has been done. Some stibnite-bearing lodes are known on Prince William Sound, on Kenai Peninsula, and in the Nizina district, but so far as has been ascertained none of these have been sufficiently developed to determine whether the ore occurs in commercial quantities. If the demand for antimony ore continues, these deposits are worthy of careful prospecting, for they are accessible to transportation throughout the year.

In an emergency demand for antimony and with the attendant high prices the stibnite mines of Fairbanks and Nome should be able to increase their annual output at once to, say, 4,000 tons. This ore, however, could be shipped only during the summer. The output might be very greatly increased if some of the stibnite deposits on or near the Pacific seaboard were found to be large enough for profitable exploitation.

LEAD.

The total lead output of Alaska mines is 2,080 tons, of which 820 tons was produced in 1916, 437 tons in 1915, and 28 tons in 1914. Most of the lead has been recovered from gold ores. The large increase in output in the last two years is due to the development of the large lode mines of the Juneau mainland belt, which carry considerable galena. Some lead was also recovered from galena ores shipped from several localities in Alaska. Galena-bearing lodes occur in the Ketchikan and Wrangell districts of southeastern Alaska, and these afford a possible field for comparatively rapid development. A test shipment of galena was made in 1916 from the Fairbanks district. The ore also occurs in the Fish River basin of Seward Peninsula and has been reported in the Broad Pass region, in the Mentasta Pass region, in the Koyukuk district, and at numerous other localities. Few if any of these occurrences are near enough to transportation to justify the hope that they could be made to contribute to the lead supply, even if the ore bodies are large enough to justify development. Galena ores rich in silver would, of course, bear heavy transportation charges. At best, however, they would not be expected to contribute enough lead to increase Alaska's total output materially. Therefore the continuation or increase of Alaska's present lead output is dependent on the operations of the low-grade auriferous lode mines of the Juneau district. It is not unlikely that similar deposits may be discovered in other parts of southeastern Alaska, but it will require many years of development work to bring them to a productive basis.

PLATINUM.

Small quantities of platinum have been found in a number of placer districts in Alaska, and traces of this metal occur in the copper ore of the Goodro mine, in the Ketchikan district. In 1916 the Alaska placer miners began to pay attention to the finding of platinum, and as a result about 10 or 12 ounces was recovered, chiefly from the placers of the newly developed Koyuk district, in the southeastern part of Seward Peninsula, also from Bear Creek, in the Fairhaven district of Seward Peninsula, and from Slate Creek, in the Chistochina district of the upper Copper River basin. It is not known that there are in any of these districts placers which could be profitably worked for their platinum content alone. The present high price of the metal will stimulate the prospectors to give special heed to the platinum concentrates, and undoubtedly there will be a larger production in 1917 than there was in 1916.

Platinum has also been found on Boob Creek, in the Tolstoi region of the Innoko district. Prof. Herschel C. Parker reports considerable platinum in the gravels of Kahiltna River. His information is based on drilling of gold placer ground with a view to installing dredges. Small quantities of platinum are also reported in the beach placers of Lituya Bay and of Red River, Kodiak Island. Less definite information has been received of the presence of platinum in some of the creeks of Kenai Peninsula.

Those of the deposits above reported that occur in shallow placers, perhaps all except the one on Kahiltna River, can be developed rapidly by use of the ordinary manual methods of mining. The Kahiltna River deposit will require the installation of a dredge, which Prof. Parker reports he is proposing to put in but which can not be ready for operation until the summer of 1918.

The outlook for some platinum production from Alaska during the next two years is hopeful, though as yet there is not a single mine in the Territory that has produced more than a few ounces. More definite information about the occurrences mentioned will be available in the fall of 1917, after certain field investigations are completed.

CHROMITE.

It has long been known that some chromite deposits occur on the southwest end of Kenai Peninsula. Two localities of this mineral are known, one near Port Chatham and the other about 7 miles inland from Seldovia. It is not known whether these deposits are of commercial size, but they are to be examined this summer. Their association with ultrabasic rocks suggests that they might also carry platinum. Some small veins carrying chromite have been found in the Tolovana district of the Yukon-Tanana region. The above meager facts indicate that there is no certainty that Alaska deposits could be depended upon for chromite in the immediate future.

NICKEL AND COBALT.

A copper lode recently discovered near Pinta Cove, on the west side of Chichagof Island, in the Sitka district of southeastern Alaska, is reported to carry nickel and a little cobalt. A specimen of ore which carries considerable nickel has been received from George R. Goshaw, who reports that it was taken from a lode not far from Spirit Mountain, in the lower basin of Copper River, but the exact locality has not been learned. Some years ago a copper-bearing lode which was reported to carry nickel was found near Canyon Creek, in this same general region. This locality is about 12 miles from Spirit Mountain and may be the one from which the specimen sent by Mr. Goshaw was obtained. Little is known about the geology of these localities where nickel has been reported or the extent of the deposits. They are to be investigated this summer. Both are accessible throughout the year, one being on tidewater and the other probably not over 10 miles from the railroad.

QUICKSILVER.

Quicksilver-bearing lodes occur in the lower Kuskokwim region and in the adjacent parts of the Yukon basin. The most accessible of these deposits and the only ones that have been prospected are on or close to Kuskokwim River. The best known of these prospects is the Parks property, on the west bank of the Kuskokwim about 330 miles from its mouth. Here some cinnabar ore has been retorted, and the quicksilver thus produced was sold to the placer miners of Seward Peninsula. There has been some prospecting of other quicksilver deposits in this general region, but so far as known no properties have been sufficiently developed to give assurance of a definite output. The deposits could be made productive with little equipment, but there is no information on which to base an estimate of their possible quicksilver yield.

The lower Kuskokwim Valley is readily accessible during the summer. Small ocean vessels can ascend the Kuskokwim as far as Bethel, and river steamers fully 500 miles farther.

MOLYBDENITE AND BISMUTH.

Molybdenite-bearing lodes are reported to have been found near Skagway and on Lemesurier Island, in southeastern Alaska; on Canyon Creek, a tributary to the upper Chitina River, which flows into Copper River; and in the Willow Creek district. It is not known whether any of these lodes are large enough to permit commercial development. The molybdenite deposits of southeastern Alaska and of the Willow Creek district are readily accessible throughout the year. No molybdenite has been produced in Alaska.

A small bismuth-bearing vein has been found on Charley Creek, in the Nome district, but is undeveloped. Bismuth has been found in gold prospects at two localities in the Tanana Valley—on Eva Creek, a tributary to Totatlanika Creek, and on Melba Creek, in the Fairbanks district—but nothing is known of the extent of these deposits. There has been no production of bismuth in Alaska.

IRON.

Iron ores are rather widely distributed in Alaska. Magnetite occurs in association with some of the copper deposits of the Ketchikan and Iliamna districts and also in a deposit near Haines, in southeastern Alaska. In the Lake Clark district there is a vein of specular hematite carrying some copper. Considerable bodies of iron ore have been found in the Nome district. Most of these deposits are undeveloped. If there were a demand for iron on the Pacific coast, some of the iron ores could be made available in a comparatively short time.

COAL.

By G. C. Martin.

The coal of Alaska, which occurs in many parts of the Territory and which includes many grades ranging from lignite to anthracite, should be grouped in a consideration of possible development into the fields that are or can be made immediately accessible and the fields that are remote or inaccessible. A further grouping should be made on the basis of the adaptability of the coal for special uses.

The coal fields that are now or can soon be made accessible include those of the Pacific seaboard and the Nenana field, which will be accessible both to the coast and to the placer camps of the Tanana Valley when the Government railroad is completed. The other coal fields of the interior and northern part of Alaska can be developed in the near future only for minor local use. The accessible coal fields of the Pacific seaboard include the Matanuska field, with high-grade steam and coking coal and low-grade bituminous coal, which is now accessible by the Matanuska branch of the Government railroad; the Bering River field, with high-grade steam, smithing, and possibly coking coal, as well as anthracite (mostly crushed), which can be made accessible by the completion of a short railroad, now under construction;[1] the Cook Inlet field, with lignite, which is situated on tidewater and is therefore now accessible; and several small fields in southwestern Alaska, with coal of various grades ranging from lignite to bituminous, possibly including some coking coal, some of which are on tidewater and now accessible and the rest of which could be made accessible by the construction of short railroads. Of these coast fields only Matanuska and Bering River contain large amounts of coal of the quality for which there is likely to be an immediate demand. The Nenana field, in the interior, although containing coal of lower grade (lignite), will probably soon be developed on a small scale because of urgent local demand.

The possible immediate markets for Alaska coal are indicated below:

Eastern Matanuska (Chickaloon) field:
- Coke for Alaska smelters.
- Coke for Puget Sound (if relative costs permit competition).
- Bunker coal (Alaska steamers).
- Navy coal (if relative costs permit competition with coal from Bering River and Chesapeake Bay).
- Smithing coal (local and export).

Western Matanuska (Moose and Eska Creek) field:
- Locomotive fuel [2] (Chickaloon to Seward).
- Local power (Willow Creek mines).
- Domestic fuel in Anchorage, Seward, Valdez (?), and Cordova (?).
- Locomotive fuel on Copper River Railroad (if Bering River branch is not built).

Nenana field:
- Locomotive fuel (Matanuska Junction [3] to Fairbanks).
- Power and thawing (mines in Tanana Valley).
- Domestic fuel (Tanana Valley).
- River-boat fuel.

Bering River field:
- Locomotive fuel (Controller Bay Railroad).
- Locomotive fuel on Copper River Railroad (if Bering River branch is built).
- Coke for Alaska smelters (if competition with Matanuska coke permits).
- Bunker coal (Alaska steamers).
- Navy coal (if competition with coal from Chesapeake Bay permits).
- Smithing coal (local and export).
- Domestic fuel in Cordova and Valdez (if Bering River branch is built).

[1] The railroad that is now under construction from Controller Bay will, according to present information, reach only the patented coal claim in the eastern part of the Bering River field and will not furnish access to the high-grade steam and coking (?) coal in the central and western parts of the field. There would be no difficulty, however, in extending the railroad into those areas.

[2] The lower-grade coal from the western part of the field should be used for locomotive and power-plant fuel because the high-grade (Chickaloon) coal is too valuable for this purpose.

[3] Nenana coal should be used on the greater part of the railroad (rather than the better and nearer Matanuska coal) because the heavy freight traffic will be northbound, leaving southbound empties available for hauling coal.

None of the uses indicated above calls for a large quantity of coal, and there will probably be no physical difficulty in developing the mines, within a few months after the time when transportation is is available, to a sufficient extent to supply the present demands. In fact, it is probable that the most serious difficulty will be that of finding a sufficient market to justify the opening of the mines on a scale large enough to permit the coal being mined and shipped at a profit.

It is public policy rather than any reasonable hope of even moderate private profit that calls for the development of the Alaska coal fields on a large scale. The reasons for the present urgent need of developing the coal fields are as follows:

1. To provide fuel for the Alaska railways.
2. To furnish the Alaska railways with the freight without which they can not be operated save at a loss.
3. To furnish cheap fuel for the Alaska mines and towns in order that the production of other necessities may be encouraged.
4. To furnish bunker coal for Alaska steamers, so that they may not be compelled to use cargo space in carrying fuel for the return voyage (on the assumption that other demands for California oil will be so great that the Alaska steamers can advantageously use local coal rather than California oil).
5. To provide coke for local smelters so that cargo space may be saved by shipping metal rather than ore and that the development of new metalliferous mines may be encouraged.
6. To provide a quickly accessible reserve of high-grade fuel for the Navy or for other urgent need.

In conclusion, although there are no difficulties (given transportation and a market) that will prevent the quick development of the few small mines that can supply the demands that can be foreseen at present, the opening of the coal fields on a large scale is quite a different problem. The development of a large coal mine requires considerable time, even under favorable circumstances. In Alaska it is not merely a simple matter of expanding the workings to a point where there is room for enough miners to produce the required tonnage. This must be done, but first there must be a slow process of prospecting, drilling, and experimental mining in order to determine where the coal for a large mine is to be found and what the method of working the mine is to be. These problems have not yet been solved in the Alaska coal fields, and consequently there is no assurance that a large tonnage of high-grade coal could be quickly obtained for the Navy or for other emergency use. This condition, in the writer's opinion, requires not only that the small mines which can supply the present demand should be opened at once, but that every possible encouragement should be given for the development of the Alaska coal industry.

PETROLEUM.

Petroleum has been found in four districts along the Pacific seaboard. These are the Yakataga field, which is comparatively inaccessible on account of the lack of a harbor; the Katalla field, which is the only one that is producing oil and which can be made tributary to Controller Bay without great expense for construction and without great loss of time or can be reached by an easily constructed 60-mile branch from the Copper River Railroad; the Iniskin Bay field, on Cook Inlet; and the Cold Bay field, on the Alaska Peninsula. The last two are tributary to harbors that are free of ice throughout the year.

Drilling has not been sufficient in the partly developed field at Katalla to determine the presence of any considerable pools. The rather wide distribution of seepages and the results of the drilling of some 25 holes indicate that oil might be obtained in this field in a much larger quantity than that now yielded by the five or six wells that are being pumped. The petroleum from this field, like that from other Alaska fields, is a high-grade refining oil with a paraffin base. As oil of this grade is now in great demand for the manufacture of gasoline, and as the supply under war conditions may not meet the needs, every encouragement should be given to those who are willing to spend the money necessary for the drilling. Unless a large pool is struck early in the operations, which is not believed probable, it will take at least a year to drill a sufficient number of holes to assure any considerable production. This statement is based on the records of the existing wells. The producing wells are shallow and the oil has to be pumped. To meet the present emergency it will probably be best to drill a large number of shallow wells rather than to attempt to test the ultimate possibilities of the field by sinking deep holes. The above statement of conditions and possibilities in the Katalla field probably holds, in general, for the Iniskin and Cold Bay fields. In these fields, however, there has been very little drilling and no production. The geologic structure of these fields, so far as known, is simpler than that of the Katalla field, and it is therefore easier to direct operators to the most probable locations of possible pools.

The Alaska oil lands were withdrawn from entry in 1910. A small area of oil land has been patented in the Katalla field, and other claims are still pending. If the Alaska oil fields are to be regarded as a possible source for refining oil during the present emergency, immediate action should be taken by which operators can obtain freehold or leasehold titles to sufficient areas to justify the large expenditures necessary for drilling.

MISCELLANEOUS MINERALS.

There is one gypsum mine on the east side of Chichagof Island, in southeastern Alaska, but no information is at hand as to the size of this deposit, and no other gypsum has been found in the territory.

Graphite deposits of commercial quality and extent occur on the north side of the Kigluaik Mountains, in Seward Peninsula. Two of these deposits have been opened and have yielded some graphite, though none has been shipped. Graphite from these deposits can be shipped only during the open season.

Two barite deposits are known in Alaska, one in the Wrangell district and one in the Ketchikan district. Both are on tidewater, accessible throughout the year, and are capable of rapid development. Some small shipments have been made from one of these deposits.

Sulphur is known to occur on Makushin Volcano, Unalaska Island, at the east end of the Aleutian chain. This deposit has been but little prospected, and its extent is unknown. Makushin Volcano is about 5,700 feet high, and its summit lies about 6 miles from Makushin Bay, the nearest harbor. Unalaska Island is unforested, and all timber for use in construction would have to be brought from a distance. This sulphur, even if it proves to be present in commercial quantities, could not be made available without much preparation for mining. Sulphur deposits are also reported on other volcanoes of the Aleutian chain, notably on Akutan Island. The above facts indicate that Alaska sulphur could not be made available for any immediate demand.

COPPER.[1]

By B. S. Butler.

After the war broke out it was generally believed that the copper industry would suffer seriously from the stopping of export trade to countries that had taken a considerable part of the American production and from decrease in the use of copper for ordinary purposes elsewhere. This belief found expression in the immediate curtailment by the larger producers of 30 to 50 per cent, and some small producers ceased operations entirely.

By the beginning of 1915 it was becoming apparent that the early fears of a disastrous effect of the war on the copper industry of this country were without foundation. There was a steadily increasing demand for copper, with a corresponding increase in price which, with slight fluctuations, has continued through the years 1915 and 1916 and into 1917.

As soon as it became apparent that the demands could not be supplied by the existing plants, steps were taken to increase the producing capacity. Many mines were able to respond quickly to the new demands, but the response of metallurgic plants was not so rapid. The flotation process, which was just being introduced in many concentration plants, served a double purpose by increasing the capacity of mills without the necessity of greatly enlarging the general plants and by producing a concentrate of higher grade, thus adding to the capacity of the smelters. Several of the large smelters had recently been rebuilt or were in process of reconstruction, so that the smelting plants of the country were unusually well prepared to meet exceptional demands. It was possible to make enlargements rapidly enough to furnish all the copper that could be treated by refineries. The refineries have been the slowest to respond but in 1917 will probably be able to refine all the copper required, though in May, 1917, enlargements of plants were still being made.

The changes in the copper industry during the last decade are shown in the accompanying table, compiled by the Geological Survey, and are graphically set forth in the diagram (Pl. I).

[1] For a more detailed discussion of the copper industry and the copper districts the reader is referred to U. S. Geol. Survey Mineral Resources, 1915, pt. 1, pp. 656–722, 1916.

Principal features of copper industry, 1907–1916.

Year.	Refined copper, primary.	Secondary copper.	Smelter production, domestic ores.	Imports.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
1907	1,032,500,000		868,900,000	252,600,000
1908	1,137,900,000		942,500,000	218,700,000
1909	1,391,000,000		1,092,900,000	321,800,000
1910	1,422,000,000		1,080,000,000	344,000,000
1911	1,433,800,000	214,000,000	1,097,000,000	334,600,000
1912	1,568,100,000	275,000,000	1,243,000,000	410,000,000
1913	1,615,000,000	273,000,000	1,224,000,000	408,700,000
1914	1,533,700,000	255,700,000	1,150,000,000	306,000,000
1915	1,634,200,000	392,200,000	1,388,000,000	315,600,000
1916	2,259,000,000	a 662,000,000	1,928,000,000	462,000,000
Average	1,502,750,000	345,000,000	1,201,400,000	337,400,000

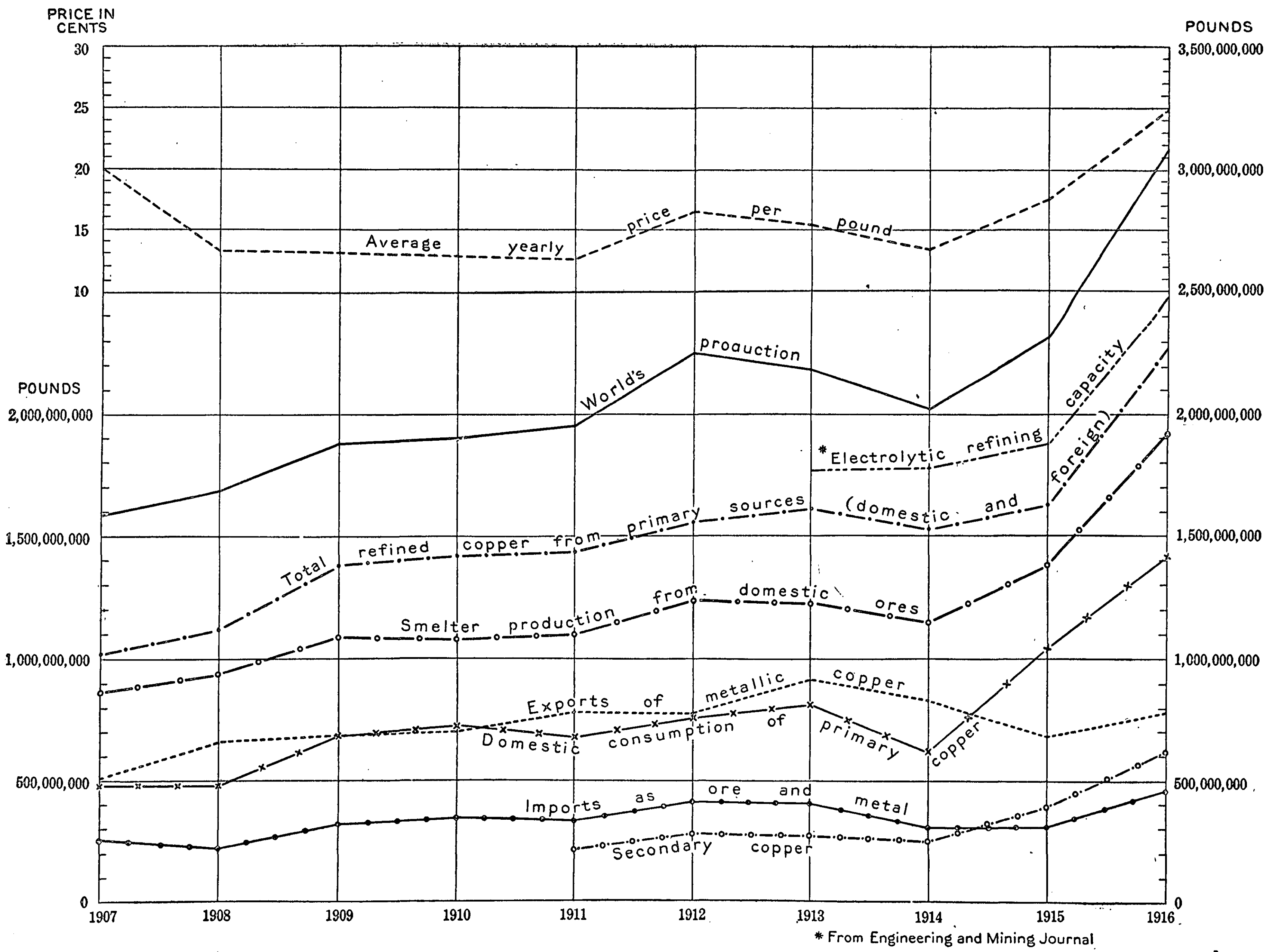
Year.	Exports of metallic copper.	Domestic consumption.	Average yearly price per pound.	World's production.
	Pounds.	*Pounds.*		*Pounds.*
1907	508,900,000	487,700,000	$0.200	1,589,000,000
1908	661,800,000	479,900,000	.132	1,683,000,000
1909	682,800,000	688,500,000	.130	1,875,000,000
1910	708,000,000	732,000,000	.127	1,903,000,000
1911	786,500,000	681,700,000	.125	1,958,000,000
1912	775,000,000	755,900,000	.165	2,259,000,000
1913	926,000,000	812,000,000	.155	2,198,000,000
1914	840,000,000	620,000,000	.133	b 2,036,000,000
1915	681,900,000	1,043,000,000	.175	b 2,339,000,000
1916	784,000,000	1,430,000,000	.246	b 3,078,000,000
Average	735,500,000	773,000,000	.163	2,092,000,000

a Preliminary figures, subject to correction. b From Engineering and Mining Journal.

The Survey reports a rather steady increase in the production from domestic ores up to the beginning of the war, which was followed by a sharp decline for a few months, and this in turn by a very rapid increase that has continued into 1917. The enlargement of existing plants and the addition of plants in construction during 1916 will permit a continued increase for 1917 if the stimulus of high prices also continues. The steady increase in the amount of copper recovered from scrap is an important factor in the supply.

Imports of copper as ore and blister copper for treatment had, like domestic production, been steadily increasing before the war and also suffered a decline when the war began, followed by an increase. There is likely to be a more rapid increase for the next few years, owing to the added production in South America, Cuba, and some other countries, though this may be offset to some extent by the refining in Canada of some blister copper from producers whose output has previously been refined in this country.

Exports of metallic copper had showed a rather steady increase until the beginning of the war, after which they declined rapidly, owing to the cutting off of exports to the central powers. There has been some recovery, but for 1916 the exports were still below those of the period immediately preceding the war. The exports of copper in



CURVES SHOWING PRINCIPAL FEATURES OF COPPER INDUSTRY, 1907-1916.

manufactured form, however, were notably larger. Exports of metallic copper in 1917 have thus far been much larger than those for any equal period in 1916. During the war the exports of copper in raw or manufactured form are likely to continue at the present rate and possibly to increase. Domestic consumption during the last two years has greatly increased over that preceding the war, though much of the copper consumed was exported in manufactured form.

The price of copper has varied greatly during the last 10 years. At the beginning of that period it was exceptionally high, as it has also been in the last two years. The averages of the yearly average price of electrolytic copper for the 10 years preceding the war, 1904 to 1913, as given by the Engineering and Mining Journal and by the American Metal Market and Daily Iron and Steel Report, were, respectively, 15.060 cents and 15.550 cents a pound. For the five years preceding the war, 1909 to 1913, the averages were 13.941 and 14.300 cents. From a date early in 1915 to the end of 1916 there was a general upward trend in the price, interrupted by declines for short periods. In the early months of 1917 the upward tendency apparently ceased, and there has been a slight decline that seems likely to persist, owing to the fact that refinery production now seems to equal the demand.

It has not been possible for the Survey to compile data showing the average cost of all the copper produced. For several years before the war a large proportion of the copper was produced at a cost of less than 10 cents a pound, and it was the general belief that the average cost of the production did not exceed 10 cents. The curtailment of production at the beginning of the war doubtless caused an increase in average cost, even with the lowering of wages. The great increase in production that followed gave opportunity to operate plants to their full capacity, and in spite of increase in cost of labor and material many companies showed a decrease in cost of copper in 1915 over previous years. More copper was doubtless produced at a cost of 10 cents or less a pound in 1916 than in any previous year, though the increase in the amount of copper produced from mines that are not operated at normal prices, together with some increase in the cost of much of the copper, possibly resulted in a slight increase in the average cost of the output for 1916 as compared with the average before the war.

The known supply of copper ore in the United States has been greatly increased during the last few years. This gain has been due in part to the development of deposits but even more to the improvement in mining and metallurgic methods. It is doubtless safe to say that for several years mining and metallurgic improvements have added to the reserves more copper in material that was previously below commercial grade than has been extracted during the same period. The copper that is being made available in the tailings of earlier operations would in some districts doubtless go far toward equaling the current production.

There is much difference of opinion regarding the future demand for copper produced in the United States. Some factors regarding this demand seem to be fairly certain. As long as the war continues there will doubless be a large if not increasing demand. At the end of the war there will be a large need of metals for reconstruction. When normal conditions are restored there will have been a very large increase in the copper-producing capacity of countries outside of the United States, including South America, Africa, British Columbia, Japan, Russia, and other countries, as well as in that of this country, and unless the increased consumption continues the competition in the copper market will be keener than before the war. The consumption will doubtless be largely influenced by the price, and the continuance of the industry on the present scale will probably necessitate a very great reduction in the price.

LIMESTONE AND LIME.

By G. F. Loughlin.

DISTRIBUTION AND QUALITY.

Limestone, including high-magnesium limestone or dolomite, has been demonstrated by work of the United States Geological Survey to be so widely distributed and so abundant in the United States that there is no doubt whatever of an adequate supply to meet all unprecedented demands, even though it is realized that stone sufficiently pure to yield lime of the highest grades forms but a small fraction of the whole. Limestone is quarried and lime is manufactured in 43 of the 48 States, and large deposits are favorably situated with respect to industrial centers, especially in the Central and Eastern States.

The northeasternmost deposits worked are in the Rockland district of southern Maine and include both high-calcium and magnesian limestone of excellent quality. Although these deposits are small compared to the vast supplies of the Middle Atlantic and East Central States, their position near tidewater has made Maine one of the foremost of the lime-producing States, with principal markets in eastern New England and New York.

Limestones and dolomites are present in both eastern and western Vermont. The western belt, which includes the famous marble deposits, is by far the more valuable. It extends southward through western Massachusetts and Connecticut and eastern New York. The larger part of the rock in this belt is of dolomitic character, but the great extent of the high-calcium rock in it may be realized when it is remembered that practically all the enormous output of marble, as well as of lime, in Vermont, Massachusetts, and Connecticut is high-calcium rock of excellent quality.

Limestones in northern New York are prevailingly high in calcium but include considerable dolomite. They extend in a nearly continuous semicircular belt along the west shore of Lake Champlain, southwestward to the vicinity of Saratoga Springs, then westward and northwestward to the east end of Lake Ontario. Another belt extends eastward from Buffalo through the large cities of central

New York to Albany, then southward to Kingston, and southwestward into New Jersey and Pennsylvania.

In eastern Pennsylvania this main belt is flanked on the southeast by areas of high-calcium and high-magnesium limestones, which supply high-grade material to the region around Philadelphia, Pa., and Wilmington, Del., and include some of the largest lime plants in the country. The main belt, which also includes high-calcium and high-magnesium rock, extends continuously from Easton, Pa., southwestward across Maryland, along the great valley region of Virginia and eastern Tennessee, across the northwest corner of Georgia, and into Alabama as far as the Birmingham district. Other belts, relatively narrow, extend in sinuous courses through western and central Pennsylvania, western Maryland, and eastern West Virginia, joining the main belt in southwestern Virginia. These immense supplies of limestone consist prevailingly of relatively impure rock, some of which is adapted for manufacturing natural cement or, when mixed with shale from neighboring deposits, for manufacturing Portland cement; but the quantity of high-grade rock present is not only sufficiently extensive for all commercial demands but also well situated with respect to markets, as is shown by the fact that Virginia and West Virginia are among the first six and Tennessee and Alabama among the first fifteen of the lime-producing States. The great quantities of furnace flux used in the Birmingham district, Ala., are of high-grade dolomite from this extensive belt. Published analyses of high-grade dolomite in this belt are few, but the deposits they represent are so distributed as to indicate that workable beds are present throughout the length of the belt.

In the Carolinas limestones occur principally in small beds which are too poorly situated and in which the rock is too impure to be of more than local interest. The deposits at Boilstone, N. C., and Gaffney, S. C., however, yield or have yielded high-calcium lime of good quality.

The limestone deposits in the Coastal Plain region of the Southern States include for the most part marls and soft limestones, too impure to be of more than local interest for the production of lime. The only lime-producing center of importance is Ocala, Fla. High-grade material is known to be present at several other places, but very few of these are near industrial centers.

The broadest and most continuous limestone area in the country extends through parts of all the Central States. Its northern limit in the United States is along Lake Huron, in northern Michigan. From this region it extends in a belt of prevailingly magnesian limestone through eastern Wisconsin to northern Illinois, where it divides into an eastern and a western branch. The eastern branch extends from the Chicago district into Indiana and Ohio, both States containing immense quantities of high-calcium and high-magnesium stone of great commercial importance. The belt continues southward through Kentucky and middle Tennessee to northern Alabama but has been relatively unproductive in these States, although some of its beds contain high-calcium stone of excellent quality. Dolomitic limestone occurs near Louisville, Ky.

The west branch of the great dolomitic belt in northern Illinois extends into Iowa and southern Minnesota. In Iowa it is continuous with high-calcium limestone that extends southward into Missouri, where it divides into two branches, one following Mississippi River to Cape Girardeau and connecting across southern Illinois with the deposits in Kentucky, the other extending westward and southwestward into Arkansas and Oklahoma and the southeast corner of Kansas. These two branches nearly surround a great area of dolomitic limestone in the south-central part of Missouri and the northern part of Arkansas.

Besides these vast and commercially important deposits, there are several beds of high-calcium limestone in Kansas, Oklahoma, Texas, Colorado, Wyoming, and South Dakota. In and across the Rocky Mountains extensive deposits of limestone and dolomite are present in every State. The small production of the majority of these States is quite in contrast with the extent of the deposits, which have been systematically developed only where they are sufficiently accessible to large cities.

PRODUCTION, IMPORTS, AND EXPORTS.

PRODUCTION.

The importance of limestone in the mineral industry is shown by the quantity and value of limestone and lime sold in the United States from 1911 to 1915, the latest year for which complete statistics are available.

Limestone and lime marketed in the United States, 1911–1916.

	Limestone (value).	Lime.		
		Quantity (short tons).	Value.	Average price per ton.
1911	$33,897,612	3,392,915	$13,689,054	$4.03
1912	36,729,800	3,529,462	13,970,114	3.96
1913	38,745,429	3,595,390	14,648,362	4.07
1914	33,894,155	3,380,928	13,268,938	3.92
1915	35,229,866	3,589,699	14,336,756	3.99
1916	(a)	[b] 4,150,000	[b] 17,845,000	[b] 4.30

[a] Figures not yet available. [b] Estimated.

Of the total value of limestone recorded, which does not include that used for Portland cement, about two-thirds represents crushed stone and building stone of different grades. The remaining third represents stone used for furnace flux and in chemical industries, the most important of which are alkali works, carbonic acid plants, glass factories, and paper mills. About one-third of the total lime is used in the building industry. The remainder is used mainly in agriculture, chemical works, paper mills, tanneries, and sugar factories.

The foregoing table shows decreases for both limestone and lime in 1914, when the early stages of the European war caused a general industrial depression. This depression, especially in the building trades, lasted until late in 1915, and the recovery in production for that year is due principally to a revival of metallurgic and chemical industries which overshadowed continued decrease in the production of crushed stone and most kinds of structural stone. The marked increase in production in 1916 may be inferred from the great gain in estimated sales of lime, which was accomplished in spite of shortage of labor and cars and large increase in cost of production. In fact, the quantity of lime that can be produced in the United States to meet unprecedented demands is limited by the capacity of limekilns, the supply of labor and fuel, and adequacy of transportation facilities rather than by the quantity of available stone.

IMPORTS.

Imports of limestone and lime represent only an insignificant part of the total quantity consumed annually in the United States, amounting in 1915 to 2,224 tons, valued at $21,707. By far the greater part of these imports comes from Canada, which in 1915 supplied 1,727 tons, valued at $15,290. This quantity should be affected at present only by conditions of labor, fuel supply, and transportation. Even if the Canadian imports were for any reason completely cut off, domestic stone or lime could be readily shipped to any of the markets affected. Imports of lime from other countries comprise specially prepared materials adapted for certain uses and in 1915 were recorded as follows by the Bureau of Foreign and Domestic Commerce, Department of Commerce: Germany, 604,000 pounds, valued at $5,547; Mexico, 227,800 pounds, valued at $723; England, 2,300 pounds, valued at $134; Japan, 1,000 pounds, valued at $11; Hongkong, 200 pounds, valued at $2. There is no apparent reason why these small quantities can not, if necessary, be displaced by domestic lime; in fact, the place of at least one European magnesian lime (Wienerkalk, or Vienna lime) is already said to have been taken by domestic lime.

EXPORTS.

Exports of lime have gone mainly to Canada, 148,458 barrels of 200 pounds, valued at $82,258, being shipped in 1915. The total exports for that year were 162,229 barrels, valued at $106,312, and included small quantities, ranging from 2 to 5,201 barrels, sent to Mexico, countries in Central and South America, the West Indies, England, Australia, New Zealand, and French Oceania. Increase in exports of lime, like that in domestic sales, is governed by the demand and facilities of production and marketing, as the supply of limestone is practically inexhaustible.

MILITARY IMPORTANCE OF LIMESTONE AND LIME.

All industries, of course, are affected directly or indirectly by the war, but some, owing to the nature of their products, have attracted particular attention. Such, for example, are operations in the iron and steel industry, including the location of armor-plate plants; the manufacture of nitrates and related products; and intensive agriculture. Other industries that would be affected by cutting off of supplies include glass manufacture, especially for optical work, and paper manufacture, for which wood pulp has been imported. Special problems caused by armies in the field, such as purification of water supply and of sewage, may also be mentioned. In all of these, as well as many more, limestone is used, and most of them require high-calcium stone of high grade (containing 95 per cent or more of carbonate). For example, limestone for optical glass must be practically free from iron and aluminum; lime for nitrate manufacture must be as free as possible from silica, alumina, iron, and magnesia. Although rock of so high a grade forms only a small fraction of the limestone deposits of the country, it is nevertheless sufficiently abundant and accessible to industrial centers.

For some uses, however, dolomite or high-magnesium lime is preferred or required. These materials are especially available for blast-furnace flux, being preferable to limestone for this purpose in some localities; for dead-burned dolomite in the basic open-hearth process of steel manufacture, where it takes the place of Austrian magnesite; for the manufacture of magnesium and magnesium salts, an industry supplied in the Pacific coast region from deposits of magnesite but made possible in the East by the cutting off of European imports; also for special grades of magnesian lime to replace material that had been imported prior to the war. Dolomite is also required in the sulphite process of paper manufacture and in certain branches of the tanning industry.

For the last two as well as certain other uses of dolomite, or magnesian limestone, freedom from more than 2 or 3 per cent of impurities is required; and one inquiry has been received by the United States Geological Survey for a dolomite containing not more than 0.05 per cent of iron. Available analyses of limestone and dolomite in which impurities, especially iron and alumina, are separately and accurately determined are relatively scarce, and it is urged that the owners of limestone and dolomite deposits hereafter have more accurate analyses of their stone and burned lime made. Even for uses where impure stone may be suitable or even required, as in sintered dolomite, the quantity of the different impurities doubtless has a direct bearing on the quality of the burned material.

There is, furthermore, a tendency on the part of some producers of building lime to investigate the influence of impurities on the workability of the lime and its strength after setting. The need of greater accuracy in limestone analyses is therefore becoming a matter of general interest to lime producers, as well as of vital importance to certain industries affected by the present abnormal conditions.

Limestone and lime for agriculture need not necessarily be of very high grade. Although insoluble impurities tend to lessen the percentage of lime available for improving the soil, they are not actively injurious to plant growth, and it may be more economical to use a local lime than to go to the expense of purchasing a higher-grade lime in a distant market. Both calcium and magnesium limestones or limes are suitable for counteracting acidity of the soil, although their use should depend on the kind of crops to be raised. The supply of limestone available for agriculture is therefore unlimited, and its widespread occurrence and low cost are important factors in the intensive cultivation during war time of land that, in recent years at least, has not been prepared for the growing of crops. From the fact that limestone and lime, by reacting with minerals of the soil, render such constituents as potash and phosphorus more available and also aid in the growth of the bacteria that render nitrogen available, it is obvious that lime will not only serve to counteract acidity of soils but in some soils will serve as a substitute for fertilizers whose price may be expected to rise with a marked increase in demand.

PORTLAND CEMENT.

By Ernest F. Burchard.

RAW MATERIALS.

Portland cement, a product obtained by finely pulverizing clinker produced by calcining to incipient fusion a properly proportioned mixture of calcareous and argillaceous materials, is now manufactured in 28 States, those not yet having active plants for making this important structural material being the six New England States, Delaware, the Carolinas, Florida, Mississippi, Wisconsin, Arkansas, Louisiana, the Dakotas, Wyoming, New Mexico, Idaho, and Nevada. The most common raw materials required for the manufacture of Portland cement are high-calcium limestone, marl, "cement rock" (an argillaceous limestone), clay, shale, blast-furnace slag, and boiler ashes of the proper composition. Combinations of two or more of these ingredients are generally used in order to supply the necessary lime, silica, and alumina. Coal, crude petroleum, or natural gas are the fuels used in burning cement in the kilns.

DISTRIBUTION OF PORTLAND CEMENT MILLS.

The natural raw materials for cement are widely distributed, as has been shown by field work done by the United States Geological Survey, and there are few States that do not contain them in sufficient quantity for the manufacture of Portland cement. The distribution of Portland cement mills, however, has been controlled for the most part by markets and transportation facilities, considered in connection with adequate supplies of suitable raw materials and fuel. The large amount of capital required for the construction and operation of a cement mill—ranging from \$500,000 for a small plant to five or six times that amount for one of the larger plants—has necessarily restricted the distribution of honestly promoted plants to localities in which the chances for success are greatest. In late years competition in the cement-manufacturing business has been very great, and this has further restricted the establishment of new plants.

If the distribution of cement mills is considered with reference to national defense, a glance at a map showing location of all the mills in the United States[1] brings out the fact that they are for the most part ideally situated for quickly supplying cement to seacoast cities and yet are generally remote enough from the coast to be immune from direct attack by sea forces. The New England coast points can be advantageously supplied with cement by mills in the Hudson River district of New York; the New York, New Jersey, and Delaware coasts can obtain cement quickly from plants in the Hudson River district and in the Lehigh district of eastern Pennsylvania and western New Jersey; the Maryland and Virginia coasts from plants in those States, one of which is situated near Norfolk, Va.; the Carolina, Georgia, and Florida coasts from plants just west of the Appalachian front in Tennessee, Georgia, and Alabama. Gulf of Mexico points can be supplied by plants in Alabama, Oklahoma, and Texas, only one of which (at Houston, Tex.), is near the Gulf. The Pacific coast is supplied from groups of mills in southern California, around San Francisco Bay, near Portland, Oreg., and near Puget Sound. Cities on the Great Lakes can get cement from many mills in northern New York, western Pennsylvania, northern Ohio, Indiana, and Illinois, the southern peninsula of Michigan, and the mill at Duluth, Minn. Along the Mexican border there are long stretches that are remote from supplies of Portland cement, but mills in southern California, near Phoenix, Ariz., and at El Paso and San Antonio, Tex., should be able to deliver what is needed.

MILITARY IMPORTANCE OF PORTLAND CEMENT.

Portland cement is used mostly as an ingredient in concrete, a mixture of cement, sand, and gravel, broken stone, or slag, and to a smaller extent in mortar and plaster, where it is mixed with sand alone. The cement usually constitutes about one-ninth to one-seventh by volume of the mixture. When sufficient water is added the cement, which is the most finely divided of these materials and consequently most intimately mixed with the others, takes up water of crystallization, forming complex silicates of calcium and aluminum. This crystallization is termed "setting" of the cement, and through its action the sand and gravel or broken stone are bound together and form a rocklike mass. The "setting" of Portland cement takes place as well under water as in the air, and consequently cement is of great value for construction work that is partly submerged. Concrete is employed in the massive form and also reinforced with steel rods, wire, and mesh, thus making possible its use in taller, lighter structures than could be built of solid concrete. Reinforced concrete has been found to offer greater resistance to fire, earthquake, and shock of explosions than other forms of structural materials.

[1] Burchard, E. F., Cement in 1914: U. S. Geol. Survey Mineral Resources, 1914, pt. 2, pp. 221-259, 1915; Cement in 1916: Idem, 1916, pt. 2, pp. 341-375, 1918.

Concrete possesses great adaptability to a wide variety of uses, besides being cheap, easily and quickly handled, sanitary, and durable, and these characteristics taken together render it of great military importance.

Among the military uses to which concrete is put are the construction of armories, barracks, roads, bridges, coast and interior fortifications, gun emplacements, trench linings, bombproof shelters, magazines for explosives, tunnels, retaining walls, sea walls, wharves, dry docks, water reservoirs, aqueducts, sewers, sewage-treatment works, incinerators, stables, floors, roofs, munition-factory buildings, warehouses, fuel-oil tanks, barges, and even in the interior of battleships.

INDEPENDENCE OF THE CEMENT INDUSTRY.

The United States produces more Portland cement than is consumed within the country, and the raw materials are here in abundance. The absolute independence of the industry is assured by the fact that everything needed by a fully equipped cement mill may be obtained in the United States, including pulverizing machinery, pebbles for grinding, and refractory materials for kiln lining. The further possibility of obtaining potash as a by-product at many of the cement mills lends encouragement to the production of cement at such mills, even in times when the profits from cement alone are small.

CONDITIONS IN 1914 AND LATER.

The year 1914 witnessed the first recorded decrease in annual production of Portland cement in the United States. The industry had experienced a remarkable growth during the preceding 10 years, and it was but natural that a slight check should come at this time. The average price per barrel in bulk at mills decreased 7.8 cents in 1914, and the beginning of the war in Europe may be said to have marked a period of depression in the American cement industry, from which recovery was slow at first.

The Portland cement industry showed no noteworthy developments during 1915, notwithstanding the greater activity in the metal industries. In view of the experiences of 1914 manufacturers exercised considerable caution, the result of which was a slight increase in the volume of shipments, a small decrease in the quantity of cement manufactured, and a considerable decrease in the stocks of cement on hand, all indicating a correction of the tendency toward overproduction that has manifested itself at times during the last few years. Prices in 1915 decreased 6.7 cents a barrel below those of 1914, and the estimated consumption of Portland cement per capita in the United States was 0.76 barrel, compared with 0.77 barrel in 1914. The total production in 1914 and 1915 represented from about 69 per cent to 76 per cent of the apparent actual manufacturing capacity, according to figures reported to the Geological Survey, but it is now believed that the actual capacity was greater than was reported.

In 1916 the conditions were much more satisfactory. At the beginning of the year the industry was already feeling the effects of the gradual revival of activity in construction work, and throughout the year mills in all parts of the United States were busy manufacturing and shipping cement at a rate greater than at any other time since 1913, although labor troubles and lack of freight cars operated as a handicap on production and shipments. Higher prices prevailed, and six new plants reported their first production in 1916, one each in California, Minnesota, New York, Oklahoma, Oregon, and Texas. The plants in Oregon and Texas are close to tidewater, and the one in Texas is unique in using oyster shells as the calcareous ingredient of its raw mix.

As a result of increased business in 1916 stocks of Portland cement were reduced below normal, yet the reserve of more than 8,250,000 barrels on hand at the beginning of 1917 seems sufficient for emergencies. This reserve, however, should be maintained and, if possible, even increased.

The present cement-clinker manufacturing capacity of the mills in the United States is possibly from 30 to 40 per cent greater than the normal consumption, and this surplus capacity seems likely to be maintained through the building of new mills and the enlargement of existing mills. In its bearing on the present situation this condition is encouraging, for there are likely to be large increases in the demand for cement for military purposes for use by the United States as well as by her allies. The utilization of the increased manufacturing capacity is likely also to prove an incentive for gaining new trade in the West Indies, South America, and the Orient if shipping is available.

PRODUCTION, IMPORTS, AND EXPORTS.

The production of Portland cement in the United States from 1912 to 1916 has ranged between 82,000,000 barrels and 92,000,000 barrels annually, an output far exceeding that of any other country. Average prices have been relatively low, ranging between 80 cents and $1.10 a barrel in bulk at the mills, yielding only small profits, but much higher prices are reported to have prevailed in the early months of 1917.

The imports of hydraulic cements into the United States are normally very small, but in 1916 they were almost negligible, having dropped to 1,836 barrels, compared with 42,218 barrels in 1915.

The exports have never been great, the largest quantity—that in 1912—having been only 4,215,532 barrels. In 1914, 1915, and 1916 the exports were respectively 2,140,197, 2,565,031, and 2,563,976 barrels. These quantities represent less than 3 per cent of the total production of hydraulic cements in the United States during those years. As recent increases have been due largely to greater exportation to South American countries and the West Indies, it appears that the cement trade is slowly expanding in the direction of greatest promise. The opportunities in these fields were pointed out recently by the Director of the United States Geological Survey.[1] Figure 3 shows graphically the relation between domestic production and consumption of Portland cement in the United States in the last six years.

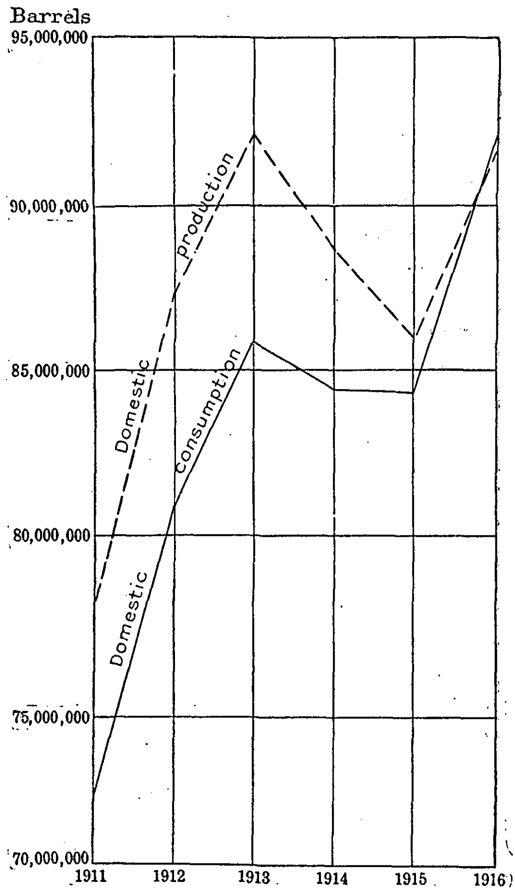


FIGURE 3.—Domestic production and consumption of Portland cement, 1911-1916.

NEEDS OF THE CEMENT INDUSTRY.

Among the present needs of the cement industry is more comprehensive and accurate information with regard to the distribution of materials suitable for concrete aggregates—especially for concrete roads—such as good clean sand, gravel, and stone available for crushing. This information can perhaps best be assembled through cooperation by the United States Geological Survey, the Bureau of Standards, and the Office of Public Roads and Rural Engineering. If funds were available the Survey could make the field examinations, collect samples of materials for test, and prepare maps and descriptions of the nature of the deposits, and the other bureaus could make the requisite laboratory studies of both raw materials and manufactured products.

[1] Smith, G. O., Our mineral reserves: U. S. Geol. Survey Bull. 599, p. 31, 1914.

CLAY AND CLAY PRODUCTS.

By JEFFERSON MIDDLETON.

CLAY.

The clay resources of the United States are almost illimitable and have hardly been touched, though billions of dollars' worth of wares have been made from them. Nor have the clays of the United States been put to many uses to which they are adapted. Except for kaolin or china clay and some of the most highly refractory clays, we are now practically independent of foreign supplies. The principal indictment against domestic white-burning clays has been the lack of purity and uniformity in the marketed raw material. Laboratory studies by the Bureau of Mines and the Bureau of Standards have shown that by proper treatment or by blending the American clays may be used for many purposes for which they have heretofore been thought unsuitable and they can be profitably used as a substitute for the imported clays.

The principal recent concern of the American manufacturers has been to find a substitute for the high-grade fire clays formerly imported from Germany and used in the manufacture of glasshouse supplies, crucibles, lead pencils, emery wheels, etc. At the beginning of the war the users of these clays were apparently well supplied with them. As stocks became depleted, with no prospects for a resumption of imports, the manufacturers of high-grade refractory products turned to the United States Geological Survey and other Government bureaus for information as to sources of domestic clays suitable for these uses. Such clays have been reported to the Geological Survey from Arkansas, California, Delaware, Illinois, Kentucky, Mississippi, Missouri, North Dakota, Ohio, and Pennsylvania, and lists of miners of these clays have been supplied to many inquirers. Bleininger and Schurecht,[1] of the Bureau of Standards, have shown the feasibility of substituting domestic for foreign clays and comment as follows on the situation:

The question of replacing the plastic clays imported from Europe in considerable quantities up to the outbreak of the European war has been of importance to the industries concerned. The materials which are chiefly concerned are the Gross Almerode clay for the glass and the Klingenberg clay for the graphite crucible and allied industries.

[1] Bleininger, A. V., and Schurecht, H. G., Properties of some European plastic fire clays: Bur. Standards Tech. Paper 79, 1916.

Some of the users of such materials have sought to replace these clays by individual American clays. There is no reason to believe that such clays can not be found in the United States; in fact, materials have been tested in this laboratory which approach the foreign clays in quality. It would be far better, however, to depend upon a mixture of two or more clays, representing both clays of the open and more refractory and of the dense and vitrifying variety, to secure the desired condition. Since such clays as those from the St. Louis, Mo., district have been used for years with good success in glass-pot mixtures, in conjunction with the European clays, it would not be difficult to supplement their qualities by means of materials vitrifying at lower temperatures and not subject to overburning within a considerable temperature range. Such clays, it is true, are not common, but may be found among the ball clays or semi-ball clays of Tennessee and Kentucky and in some of the plastic No. 2 fire clays, as those from Pennsylvania and Ohio.

The demand for clays to be used in the place of the English china and ball clays has not been so sharp, because the supply has not been so greatly curtailed as that of the German fire clays. Nevertheless there has been some falling off in the imports of kaolin or china clay and more or less demand for a substitute for the imported kaolin. Sproat,[1] of the Bureau of Mines, has shown that if the Georgia and South Carolina clays are treated with caustic soda and sulphuric acid, at a cost of less than 50 cents a ton, they can be substituted for the ball clay and 50 per cent of the English china clay, and that whiter and stronger tile can be made from these clays in their purified form with domestic feldspar than can be made from imported china clay and Cornwall stone. From these results, and the possibility of the successful treatment of other clays heretofore deemed unsuitable for use in the white-ware industries, together with the fact that large deposits of white-burning clays in this country are at present undeveloped, it seems probable that the United States will become entirely independent of foreign clays.

CLAY PRODUCTS.

The direct use of clay products in war is of minor importance compared with the use of refractory products in the iron and steel and glassmaking industries and the use of clay wares in the chemical industries, which are of vital importance to military operations.

The clays of the United States form the basis of great industries. In value of annual output these products stand next to the two metals and two fuels that rank highest—iron and copper, coal and petroleum. Every State has its workable deposits of clay, and every variety of ware, from the commonest product—common brick—to the highest grade of china or porcelain, is made from domestic clay within our borders. The imports of these wares are now exceedingly small compared with domestic production, being valued in 1915 at only 4 per cent of the total output. Of the imports, 97 per cent consisted of pottery and 3 per cent of brick, firebrick, and tile.

[1] Sproat, I. E., Refining and utilization of Georgia kaolins, with a preface by C. L. Parsons: Bur. Mines Bull. 128, 1916.

The value at the point of shipment of the pottery consumed annually in the United States is about $50,000,000. The proportion of domestic production to consumption has been gradually increasing since 1907, reaching its maximum—over 90 per cent—in 1916. This increasing market for domestic pottery is due no doubt to the improvement in the texture, finish, color, and decoration of the American product and in prevention of crazing, some of the higher grades of American pottery equaling if not surpassing some of the best imported wares. The value of the pottery produced in 1916 was the greatest ever recorded, the potteries during most of the year having been rushed to the limit. The output was somewhat curtailed, however, by the inability to procure raw materials on account of the transportation and labor conditions and the shortage of fuel.

The imports of pottery, which were in general declining even before the war began, have since shown even greater decrease, the value of pottery imported in 1916 being considerably less than one-half of that in 1907, the year of maximum value.

THE RARER METALS.

By Frank L. Hess.

INTRODUCTION.

Great gold placer fields, now mere wastes of overturned gravels; worked-out coal fields; exhausted gold, silver, and other mines, with their sterile dumps, gaunt head frames, and decaying shaft houses and mills, testify that, unlike manufactures and agricultural products, mineral deposits are diminishing assets, and the fact that a large production of some mineral has been made in one year does not necessarily imply that it can be repeated under the impetus of great need. In estimating the possible production of any mineral for any period, a proper weighing of the attending circumstances, the statistics of production of preceding years, and a knowledge of the deposits themselves are all necessary, and these statements probably apply more forcibly to the metals used in alloy steels than to others, for these metals occur in vastly less quantities than coal, iron, copper, or the other common metals, and the individual deposits are smaller and much less widely distributed and, unlike those of copper or iron, are in very few places concentrated from lean into richer deposits.

Comparatively restricted markets and lack of knowledge concerning these metals themselves and of the minerals in which they occur have prevented prospecting for them until within the last few years, so that as a rule developments of such deposits are small.

The subjects briefly discussed here with reference to their availability as war supplies are treated more fully in Mineral Resources and other publications of the United States Geological Survey, especially those for recent years.

ANTIMONY.

Owing to its brittleness and softness antimony has comparatively few uses. Its principal use is in the hardening of lead, which it also prevents from contracting on solidifying from a molten condition. In peace its chief uses are for bearing metals and type metals. In the manufacture of munitions the metal is alloyed with lead for shrapnel bullets. The higher specific gravity of the lead is necessary to give the bullets the required weight, and the antimony is used to give the bullets a hardness that will prevent deformation when the shell explodes.

The United States has never been a large producer of antimony ores as such, but for several years its smelters have turned out between 2,000 and 3,000 tons[1] of antimony in antimonial lead—a form quite as useful as if the metals had been smelted separately and then alloyed. The production of antimony ores in the United States in 1915, under the spur of very high prices, was 5,000 tons of ore, mined and shipped, carrying about 2,100 tons of antimony, estimated to be worth $425,000. The figures for antimony in ore take no account of the loss in smelting, probably amounting to 20 per cent. Of the ore produced in 1915, 735 tons of stibnite, carrying 58 per cent of antimony, was mined in the vicinity of Fairbanks, Alaska, and 148 tons, with an unknown metallic content, near Nome.[2] In 1916 the ore shipped from Alaska amounted to 1,390 tons, carrying about 57 per cent of antimony.[2] The Alaskan deposits are new and had not been drawn on before 1915. In the main body of the United States antimony ores were taken chiefly from deposits which had been known for a long time but which, owing to their isolation, the lack of transportation, or their small size or low tenor had been worked only during periods of high prices. Such deposits were worked in Inyo, Kern, and San Benito counties, Cal.; in Humboldt and Elko counties, Nev.; and at points in Arkansas, Idaho, Montana, Oregon, Utah, and Washington.

After the war demand became marked smelters began by demanding ores carrying about 60 per cent of antimony (Sb), but before the end of 1915 they were taking ores carrying 20 per cent and were glad to obtain impure ores from South America. Figures for the output during 1916 are incomplete, but the production of antimony in ores mined and the imports increased over those of 1915.

In 1915 the antimony supplies of the United States approximated 18,600 tons, made up as follows:

	Tons.
Antimony contained in domestic ores	2, 100
Antimony contained in antimonial lead of domestic origin	2, 800
Antimony contained in antimonial lead of foreign origin	464
Antimony recovered (in alloys) from old alloys, scrap, and dross	3, 102
Antimony in imported matte and metal	8, 500
Antimony in imported ore	1, 687

Probably the first four items, accounting for nearly half of the extraordinary supplies of 1915, could be duplicated under any great public emergency. Of the remainder, consisting of imported

[1] The short ton of 2,000 pounds is the unit used in this paper.
[2] Figures compiled by Alfred H. Brooks.

metal and ore, the great bulk, about 8,500 tons, is of Chinese origin, and practically all the rest is from South America and Mexico. On account of our friendly relations with these countries and their accessibility they may properly be relied on as sources of supply and can probably repeat the production of 1915 under similar inducements.

Alaska holds possibilities of antimony production which have been discussed by Brooks.[1]

The antimony-smelting capacity of the United States includes the following plants:

Magnolia Metal Co., Matawan, N. J.
Western Metals Co., Los Angeles, Cal.
Chapman Smelting Co., 409 Battery Street, San Francisco, Cal.
Antimony Smelting & Refining Co., Seattle, Wash.

Besides these the American Star Antimony Co., Gilham, Ark., has a plant for the electrolytic reduction of antimony, and the following firms smelt antimony and lead ores to make antimonial lead:

Metals Refining Co., Hammond, Ind.
Hoyt Metal Co., St. Louis, Mo.
International Lead Refining Co., East Chicago, Ind.
Great Western Smelting & Refining Co., Chicago, Ill.
Pennsylvania Smelting Co., Pittsburgh, Pa.
Balbach Smelting & Refining Co., Newark, N. J.
United States Metals Refining Co., Grasselli, Ind.

It must be admitted that the United States can not produce antimony in quantities equal to those now used, but it is probable that satisfactory substitutes for hardening lead may be found in using calcium, barium, strontium, magnesium, and copper.

ARSENIC.

Arsenic finds its greatest uses in insecticides, in glass making, and for dyeing, and smaller quantities are used as a weed killer, in disinfectants, in bearing metals, and for killing vermin.

So far as is known, only the white oxide is produced in this country, and very little has been made directly from arsenic minerals, because great quantities are available as a by-product in the smelting of copper, gold, silver, and lead ores.

In 1915 the United States produced, as a by-product, 5,498 tons of white arsenic, valued at $302,116. Imports amounted to 1,400 tons of white arsenic and 1,783 tons of "arsenic and sulphide of, or orpiment." The elemental arsenic amounted to probably less than 50 tons. The production in 1916 was 5,986 short tons, valued at $555,186. Imports in 1916 were 1,071 tons of white arsenic and 1,092 tons of "arsenic and sulphide of, or orpiment," valued at $232,694.

[1] Brooks, A. H., Antimony deposits of Alaska: U. S. Geol. Survey Bull. 649, 67 pp., 1916; Alaska's mineral supplies: U. S. Geol. Survey Bull. 666–P, 1917.

Considerable quantities of arsenic can easily be produced in the United States by saving more white arsenic as a by-product and manufacturing the element and the sulphide from it. Owing to the long distance of the smelters from the eastern markets, a minimum price of 4 cents a pound in New York is probably necessary for the plants to recover arsenic at even a small profit.

BISMUTH.

Bismuth, like antimony and arsenic, owing to its brittleness and softness, has very slight use alone. It is used as a component of alloys having low melting points, and as it expands on solidifying from the molten state it is used in some type and bearing metals. A number of bismuth compounds are used in treating wounds, and it is therefore of importance in time of war.

Practically all the bismuth produced in this country is obtained as a by-product in smelting copper, lead, gold, and silver ores.

The lead-silver mines at Leadville, Colo., contain pockets of ore that are comparatively rich in bismuth, but the deposits are erratic. When such ores are obtained the American Smelting & Refining Co. smelts them separately to obtain a bismuth-rich lead which is refined by the Betts electrolytic process at Omaha, Nebr.

The dusts saved by the Cottrell precipitation process at the copper smelter at Garfield, Utah, contain a considerable quantity of bismuth, and this is also extracted at the Omaha refinery, at which very complicated processes have been developed for the recovery of such by-products.

The United States Metals Refining Co. also recovers bismuth from lead refined by the Betts process at Grasselli, Ind. The bismuth comes largely from ores mined at Tintic, Utah. The ores are not themselves rich enough to work for bismuth, but the metal is left in the anode residues after the removal of the lead and is then sufficiently concentrated to be an asset.

A little bismuth ore has been produced in the Deep Creek Mountains, Utah, and near Rico and Ouray, Colo. Bismuth minerals are reported to occur in small quantities with practically all copper ores mined, especially in the deposits now being exploited in the Organ Mountains, N. Mex., and should Cottrell precipitation apparatus be put on the stacks of all the smelters the needs of the United States for bismuth in time of war could probably be met with comparative ease. No bismuth is now saved at the Anaconda smelter, yet published figures show that 800 pounds or more passes into the air each day. It would not be cheap nor easy to save the bismuth now lost, but it could probably be done if necessity arose.

NICKEL.

Nickel is now considered an essential for all good steels, except some of the special steels, such as "high-speed" steel, and it is especially useful in making armor plate. The alloy of nickel and copper known as "Monel metal," obtained by smelting the Sudbury ores without separation of the two metals, has been found very useful for valves and fittings for high-pressure steam systems, such as those used on war vessels.

Although the manufacture of metallic or practically pure nickel was developed in this country by Joseph Wharton in the seventies, the discovery and development of deposits larger than any in the United States, first in New Caledonia and then at Sudbury, Ontario, moved the center of production out of this country. However, the smelting and refining of nickel had been carried to so great a degree of perfection and the plants that had been erected were so large that up to this time the United States has remained the largest refiner.

No direct production of nickel from American nickel ores is known to have been made in this country since 1909, when the American Lead Co. operated a smelter at Fredericktown, Mo., for a short period; but in the electrolytic refining of copper the nickel, which is found in small quantity in practically all blister or other copper that has not been previously electrolytically refined, goes into solution in the electrolyte. The electrolyte must be watched in order that not more than 1 per cent of nickel shall accumulate, for a greater quantity is said to interfere with the smooth deposition of the copper and thus to cause short-circuiting and other troubles.

From the electrolyte the nickel is saved as nickel sulphate. Formerly a large quantity of nickel-ammonium sulphate was also made, but none is now reported. The other companies sell the nickel sulphate, which is used for nickel plating, but the American Smelting & Refining Co. reduces the salts saved in its refineries to metal. All other salts saved could be reduced to metallic nickel by electrolysis, with little trouble.

The first nickel known to have been recovered in this country as a by-product in the electrolytic refining of copper was obtained in 1908. During the six years 1911–1916 the saving was as follows:

Nickel content of salts and metallic nickel produced as a by-product in the electrolytic refining of copper, 1911–1916.

Year.	Quantity (short tons).	Value.	Year.	Quantity (short tons).	Value.
1911	445	$127,000	1914	423	$313,000
1912	328	93,600	1915	822	533,222
1913	241	79,393	1916	918	671,192

The imports of nickel as metal, in ore, matte, oxide, and alloys during 1915 amounted to 28,300 tons, and the exports to 13,209 tons, so that the domestic consumption for that year apparently amounted to nearly 16,000 tons. The 822 tons saved from electrolytic copper refining in 1915 therefore amounted to a little more than 5 per cent of the consumption.

The imports of nickel as metal in ore, matte, oxide, and alloys during 1916 amounted to 36,325 short tons, valued at $9,901,887. The exports were 16,702 tons, so that the domestic consumption for that year apparently amounted to 20,540 tons. The 918 tons saved from electrolytic copper refining in 1916 therefore amounted to a little more than 4.4 per cent of the consumption.

In case of urgent necessity, nickel plating and other uses of nickel, except for armor plate and other war appliances, could be somewhat curtailed, and although armor plate of good quality can be made without nickel, it is so valuable in this connection that common sense would seem to demand the utilization of all possible sources in the United States until every war need has been met.

The principal nickel deposits in this country as now known are apparently the deposits worked in the past by Wharton and others at Gap, Pa.; sulphide of nickel and cobalt (linnaeite) with lead, copper, and iron sulphides in dolomite near Fredericktown, Mo.; nickel-bearing veins on the east side of the Stillwater Range, 45 miles southeast of Lovelock, Nev.; sulphide-bearing amphibolite dikes near Key West, Nev.; genthite deposits in Nickel Mountain, 3½ miles west of Riddles, Oreg.; and a deposit 4 miles south of Julian, San Diego County, Cal., in connection with an amphibolite dike. A complete digest of the known facts concerning these and other nickel deposits in the United States has been published.[1]

How much could be produced from these deposits in an emergency can only be guessed at now, but were strong efforts made toward production alone probably 2,000 or 3,000 tons of nickel in ore could be obtained. For its conversion copper smelters already built could probably be used, the excess sulphur in the sulphide ores being used to sulphidize the silicate ores.

A source of nickel which, though not domestic in origin of ore, is nevertheless available is in the iron ores imported into this country from Mayari, Cuba. These ores carry not far from 1 per cent of combined nickel and cobalt, mostly nickel. The two metals go into the iron, and if this iron is used as a basis for steel, then so much less nickel will have to be added to give the desired result. During 1915, 337,004 tons of such ore was imported. No analyses are at hand showing how much of the nickel is lost in the smelting

[1] U. S. Geol. Survey Mineral Resources, 1915, pt. 1, pp. 743–766, 1917.

operation, but the percentage in the pig iron should not be less than in the ore.

The main source of the nickel now imported by the United States is Sudbury, Ontario. A very much smaller part comes from New Caledonia. Both of these localities are in countries with which the United States now holds the most friendly relations.

TUNGSTEN.

The almost indispensable place that tungsten now occupies in the making of high-speed tool steels is indicated by the price to which tungsten ores rose when, after the beginning of the European war, the full demand for lathe tool steels was felt. The highest price recorded before the war was about $15 a unit (1 per cent per ton), but in the spring of 1916 the price rose above $90 a unit, ores selling in the Boulder field, Colo., for $93.50 a unit, and in New York prices of $100 or more were said to be asked. The quantities produced increased almost as much in proportion. A slump in 1914 had brought the production for the year down to an equivalent of 990 tons of concentrates carrying 60 per cent WO_3; in 1915 the output increased to 2,332 tons, and it is probable that in 1916 it amounted to 5,200 tons. Imports during 1916 were 3,973 tons of ore, presumably carrying about 60 per cent WO_3, valued at $7,353,691, and 43 tons of ferrotungsten, valued at $157,711. Not only were the prices, production, and imports very high, but the standards of purity were temporarily lowered. Tungsten ores containing phosphorus, sulphur, bismuth, tin, and copper, which at other times would have received little consideration from most buyers, were taken readily.

After the middle of 1916, however, prices dropped considerably and by the early part of 1917 had reached $17.50 a unit for concentrates carrying 60 per cent WO_3. This price would have been considered high before the beginning of the war, but those whose easily worked ore bodies have been exhausted or who have poor deposits find the price low and are asking for a tariff that will raise it still higher.

Until the beginning of the war the United States had been able to supply its own needs of tungsten, for though at times ores, ferrotungsten, and metal were imported, the exports probably balanced or overweighed the imports.

The great demand for tool steel to cut enormous quantities of shells, rifle barrels, and other war steel overran the producing capacity of the mines, and every available known source of tungsten was drawn upon. The effect upon American deposits was far from uniform. Companies were formed whose basis for stock selling was merely a more or less shadowy title to some tract of land in the neighborhood of paying mines; some persons held claims on which they did no work, refusing large prices in the hope of receiving entirely unreasonable sums; but many deposits were worked in a businesslike manner. In a considerable number of mines, particularly in the Boulder field, the principal known ore shoots were worked out to meet the demand, and in these mines the cost of production from remaining ore bodies was materially increased.

On the other hand, some operators discovered shoots from which the ore could be removed profitably at a price as low as $6 a unit. This figure, however, does not allow expense to be put into exploratory work for other ore shoots. Creek beds and residual material near outcrops of veins were worked over by men and boys, and low-grade material from old dumps carrying ore too lean to be worked under low prices was crushed and jigged or otherwise concentrated. These sources contributed a considerable portion of Boulder County's recent production and of course yield but temporary supplies. The Boulder field produced an equivalent of about 2,260 tons of concentrates carrying 60 per cent WO_3.

A number of prospectors in other fields found deposits too late to mine ores that could be sold at the very high prices prevailing in the first half of 1916 and have done little with them. The contact-metamorphic deposits at Toulon, Humboldt County, Nev., and near Bishop, Inyo County, Cal., did not come into active production before the close of 1916.

In the Atolia district of California the production rose beyond that of any former year, though not quite equal to that of the Boulder field, and more than 2,000 tons was shipped. A quantity of scheelite concentrates was taken from the stream and residual gravels, and it is probable that this part of the production can not be duplicated, but the production from veins, forming very much the larger part, can probably be repeated under an impetus of high prices and the possible need of the country.

Very little tungsten ore was produced from the deposits in the State of Washington, but it is reported on good authority that one or more deposits should be productive, especially under the high prices that have prevailed. Data are not yet at hand to show the probabilities of future production in Arizona, South Dakota, and Missouri. Field investigation by the Geological Survey is now being made. It seems likely that the production from New Mexico might be increased. Alaska became an important producer, with 250 tons of ore, and can probably repeat the output.

High-water mark in the production of tungsten ores in this country may have been reached, but it is not impossible that under the incentive of prices reaching, say, $35 a unit, and the added zest of patriotism, the figures for 1916 might be exceeded. It may be found advisable, however, to operate many properties under Government supervision, particularly isolated deposits held by men of little means, suitable provision being made for the payment of the owners, and it might be desirable to extend such supervision to at least some of the larger mines. It is probable that under such operations some unproductive properties held only to be unloaded on some one with more means or energy, usually at prices far from reasonable, might thus be made to contribute at least a small quantity of ores which might be greatly needed.

It is not likely that so much high-speed tool steel will be needed again at one time as was needed at the beginning of 1916. Huge quantities of lathes and other metal-cutting machinery were erected in the shortest possible time, and all these had to be equipped with tools. It may not be necessary to erect many more, and those in place are probably fairly well equipped. The flow of scrap back to the steel works will be large and will correspondingly decrease the demand for new metal, so that the future draft on ores may not be as heavy as it has been recently.

The source of imported tungsten ores is of great interest. The largest part of the imported ore came from South America—Argentina, Bolivia, Peru, and possibly a little from Chile—and considerable quantities came from Mexico, Japan, Chosen, and the East Indies. In the present war it seems impracticable for an enemy to shut out these supplies.

When the great demand came in 1916 American manufacturers were called upon to supply munitions to England, France, Italy, and Russia. For our own needs our own supplies of tungsten ore would probably be ample, but should the United States further help other powers with war steel it might be necessary to call on the other nations for some tungsten supplies.

Plants now in existence for the reduction of tungsten ores to metal or ferrotungsten will probably be sufficient to handle all the ore supplied. In the main the processes are simple, and little complicated or expensive machinery is required, though ores carrying low percentages of tungsten require more careful treatment than the high-grade ores.

MOLYBDENUM.

The consumption of molybdenum in the United States and, in fact, in the world, is much smaller than that of gold, if by consumption is understood the absorption into the channels of trade or the holding in stock, which may be described as a passive use. However, in 1915, the latest year for which statistics are complete, the United States was the largest producer of molybdenum ore, although it has not been a large user.

Estimated world's production of molybdenum ores in 1915.[a]

Country.	Ore mineral.	Quantity (short tons).	Estimated percentage of molybdenum.	Weight of molybdenum (short tons).
Canada	Molybdenite	14.3	.50	7.2
New South Wales	do	35.5	54	19.2
Norway	do	87.0	45	39.1
Peru	do	3.0	49	1.5
Queensland	do	109.0	54	58.8
Spain	Wulfenite	29.0	20	5.8
United States	Molybdenite and wulfenite	3,498.0	2.6	91.0
				222.6

[a] Hess, F. L., Molybdenum: U. S. Geol. Survey Mineral Resources, 1915, pt. 1, p. 810, 1917.

There seems to have been a marked growth in the demand for ferromolybdenum during the present year, and steel makers who have not been users are now making inquiry for it.

The United States contains many deposits of molybdenite, some of which seem to be capable of supplying the country's needs in full under all discernible prospective circumstances. The large deposits are, however, of low grade—from 0.7 to 2.5 per cent.[1]

The principal deposits of molybdenum ores known are on Chalk and Bartlett mountains and Quandary Peak, in Summit County, and near Empire, on the east side of Red Mountain, Colo.; in Copper Canyon, on the east slope of the Hualpai Mountains, Mohave County, at the old Yuma mine, Pima County, and at the Mammoth and Collins mines, Pinal County, Ariz.; and near Emigrant and at other places in Montana. Many smaller deposits, or deposits on which less development work has been done, occur in practically all the Rocky Mountain and Pacific slope States.

Some of the deposits, such as the wulfenite-bearing veins at the Yuma, Mammoth, and Collins mines and the molybdenite deposits in Copper Canyon, Ariz., are now (1917) being actively exploited. The deposit on Red Mountain was rather extensively worked in 1915, but the owners later abandoned operations, assigning as a reason that they did not pay.

A large amount of experimental work has been done on the deposits in Summit County, Colo., and the owners are sanguine as to the outlook for profitable exploitation.

Should the United States Government require molybdenum in considerable quantity it might be necessary, as with tungsten deposits, to have some part of the operations carried on under the supervision of Government agents, in order to insure a supply of ore at the time needed.

[1] Horton, F. W., Molybdenum; its ores and their concentration, with a discussion of market, prices, and uses: U. S. Bur. Mines Bull. 111, 132 pp., 1916.

Some of the ores carry copper, vanadium, tungsten, and other undesirable constituents, and means for the elimination of these impurities or for their avoidance in mining would have to be taken. Much of the ore could be mined comparatively free from them, however, and there is little doubt that all the molybdenum ore necessary could be obtained within the borders of the country.

The reduction of the ore is not difficult and could be accomplished in plants already built, or, if desirable, new plants could be quickly erected.

VANADIUM.

Vanadium is probably to be classed as one of the highly desirable but not absolutely necessary constituents of high-speed and other tool steels, spring, gun, automobile, and machine steels. All are apparently improved by it, but all have been made of good quality without it.

The world's supply of vanadium is practically controlled by American firms, though the largest known deposit lies in Peru, at Minasragras. The second largest source, considered as a whole, is in the vicinity of Placerville and Vanadium, San Miguel County, Colo. There are many smaller deposits in the mines that contain carnotite (hydrous potassium-uranium vanadate) in southwestern Colorado and southeastern Utah and vanadinite (lead chlorvanadate) in New Mexico and Arizona.

The American Vanadium Co., which controls the Peruvian deposits, usually keeps large stocks of material on hand in this country, so that even should the unexpected happen and that source of supply be cut off there would probably be a considerable stock of these ores to draw on. The Peruvian ore is different from any found in this country, being a vanadium sulphide carrying an excess of sulphur. It is roasted before shipping and then carries about 25 per cent vanadium. Considerable quantities of ferrovanadium made from this ore are exported.

The ore found in the Placerville-Vanadium area, Colorado, is a light-green sandstone, the grains of which are partly cemented by roscoelite, a vanadium-bearing mica. The sandstone contains certain thin, flat veins one-half to three-fourths of an inch thick, which look like shale and have been so called and which are composed almost wholly of roscoelite and carry about 8 per cent of vanadium. From these veins the roscoelite has apparently spread into the sandstone, which may carry a maximum of 4 per cent vanadium but as mined probably carries 1 to 1.5 per cent. The Primos Chemical Co., the only company operating on these deposits, has a plant at Vanadium for the reduction of the ore to hydrous ferric vanadate. This product is then shipped to the East for further treatment. Much smaller quantities are saved as a by-product in the treatment of carnotite ores for radium. It is estimated that in 1915 about 627 tons of vanadium was produced from these two sources.

The extent of the vanadinite deposits is uncertain. The vanadinite occurs only in the oxidized parts of some lead-bearing veins, especially in New Mexico and Arizona. If efforts were made toward its recovery, perhaps 50 tons or more of vanadium might be recovered from this source, but great efforts would have to be made.

It is possible that approximately 30,000 tons of high-speed steels were produced in this country in 1916. About 0.6 per cent of vanadium is used in some of the best steels, and at this rate, one-third being allowed for waste, about 300 tons of vanadium would be required, so that if the production of this large tonnage of steel should be repeated the United States would still have one-third of its production to use in other steels.

If all outside supplies of vanadium were shut off, the worst that could be said is that the country would be inconvenienced—it would not suffer.

TIN.

Among the vagaries of ore deposits which seem to show a nonhomogenous earth, as pointed out many years ago by Becker, is the erratic distribution of the metals.

The United States is immensely rich in iron, copper, gold, silver, lead, zinc, and tungsten and, compared with other countries, has large deposits of some other metals, such as mercury, molybdenum, titanium, vanadium, uranium, and radium, but of a few metals it has, from present knowledge, a scarcity, and particularly does it lack nickel, cobalt, and tin.

In the United States proper the known tin deposits are almost negligible. A little tin is mined spasmodically in North and South Carolina, Texas, and South Dakota. Alaska produces 100 or 200 tons a year (the yield of metallic tin was 140 tons from Alaska in 1916), but when it is noted that the United States annually uses between 40,000 and 50,000 tons of tin the inadequacy of our output is apparent. Moreover, the output is not likely to be greatly increased from known deposits.

Our chief source of supply has been the Malay Peninsula, controlled by Great Britain. The only source of supply on the Western Continent is from the mines of Bolivia, whose output of about 30,000 tons is equal to about two-thirds of our imports. The Bolivian supply formerly went to Europe, mostly to Germany, for smelting. Since the beginning of the war efforts have been made, with some success, to divert this ore to the United States, and the American Smelting & Refining Co. has erected a combined smelting and electrolytic refining plant at Maurer, N. J., with estimated capacity by July 1, 1917, of 18,000 tons of tin annually, for the treatment of Bolivian and other tin ores. It is reported that another smelting company will erect a plant in this country with capacity, when in full operation, of 20,000 tons of tin a year, for smelting Bolivian ores. At the same time, all other supplies have been in the hands of friendly nations, so that our needs have been amply met.

However, if all outside supplies should be cut off the United States would be forced to turn to substitutes, such as glass and aluminum as food containers; sherardizing and galvanizing in place of tin plating for many articles; zinc, lead, or aluminum sheet in place of tin plate for many other articles; and tight folding and crimping in place of soldering. The country would frequently be inconvenienced, but it could supply the lack.

IRON.

By Ernest F. Burchard.

In view of the extraordinary developments of the iron mining and manufacturing industries in the United States since the beginning of the war in Europe, and in view of the inevitable further increase in demand for iron and steel as a consequence of the entrance of the United States into the war, it is of interest to review these developments briefly and to consider how fully it may be possible to meet these increased demands.

CONDITIONS IN 1914 AND LATER.

Prior to the beginning of the war—indeed, during nearly the whole of the year 1914—the iron industry was in a state of stagnation. Prices were low, there was but little domestic or foreign demand for iron and steel, and that little demand was easily met by the operation of mines and furnaces at a greatly reduced rate of output compared with that of the two preceding years. In fact, many companies that could have saved money by closing their mines and furnaces generously kept them in operation to an extent sufficient to support part of the army of people dependent on the wages earned in normal times.

The first effect of the European war on the financial situation in the United States was such as still further to discourage the buying of iron and steel products and to depress prices. This condition, of course, could not well be other than temporary, for, as was pointed out by the Director of the Geological Survey in Bulletin 599, published in the autumn of 1914, the interference of war with industries in the belligerent countries could not fail to reduce the output of their mines and furnaces and to enlarge the demand for American iron and steel. It also seemed probable that domestic markets on the Pacific coast, formerly supplied in large part by manufacturers in England, Belgium, and Germany, would become open to American manufacturers, as well as markets in Canada, South America, and Japan.

Such trade revivals and readjustments require time for their accomplishment, even under the impetus of war conditions, and it was not until the middle of 1915, or until the war had been in progress nearly a year, that the demand for iron ores and metals had become general throughout the United States. Not until June or July, 1915, did the price of pig iron begin to rise, and although the year closed with prices $1 to $1.25 a ton higher than at the beginning of the year, the average price at blast furnaces of all grades of pig iron for 1915 was 21 cents lower than the average for 1914.

As soon as the demand for iron ore became heavy, about the middle of 1915, it met with a ready response, particularly in the Lake Superior district, where there was an increase in shipments of nearly 45 per cent in 1915, compared with an aggregate increase of about 12 per cent in the other iron-mining districts of the United States. In 1916 the heavy movement of ore began as soon as navigation opened, with the result that more than 66,500,000 gross tons was shipped from the Lake district, an increase of nearly 41 per cent. The total shipments for the United States in 1916 amounted to 77,870,553 tons, an increase for the whole country of about 40 per cent. The increase in districts other than Lake Superior was about 41 per cent. The quantities mined, which are given in the table on page 4, differ slightly from the shipments just mentioned.

At the beginning of 1916 extraordinary activity prevailed in the iron and steel industries, and this activity was maintained with comparatively little variation throughout the year, as is indicated by the record of pig-iron production by months, which ranged between 3,000,000 tons and slightly over 3,500,000 tons. The total production in 1916 amounted to 39,434,797 gross tons, compared with 29,916,213 tons in 1915,[1] an increase of 32 per cent, following a 28 per cent increase in 1915. In the first six months of 1917 the output of coke and anthracite pig iron [2] was 19,069,892 gross tons, compared with 19,410,453 tons in the corresponding period of 1916, a decrease of about 1.7 per cent.

The general average prices of iron ore per ton at the mines for the whole United States were $1.81 in 1914, $1.83 in 1915, and $2.34 in 1916. At lower Lake ports ore prices were advanced 70 to 75 cents a ton for the season of 1916, after having remained stationary since 1914. For the season of 1917 there was a general advance of $1.50 a ton, or 2.7 to 2.9 cents a unit of iron. The 1916 and 1917 advances range between 15 and 21 per cent and 25 and 30 per cent respectively. Compared with these modest advances prices of pig iron rose greatly during 1916. Southern foundry No. 2, at Birmingham, rose from $13 to $22 a ton, an increase of 69 per cent. Southern Ohio No. 2, at Ironton, seems to hold the record with an increase from $14 to $30, or 114 per cent, and the higher grades of iron also held up well, as indicated by the rise in Bessemer iron at Pittsburgh

[1] Iron and Steel Institute. [2] Iron Age, July 5, 1917, p. 35.

from $20 to $36, or 80 per cent. In the middle of July, 1917, the price of basic pig iron at western Pennsylvania valley furnaces and of Bessemer pig iron at Pittsburgh reached $53 and $57.95 a ton, respectively,[1] the highest points since the Civil War.

With regard to the iron-ore situation, which is, of course, of fundamental importance, it was stated by the Geological Survey at the beginning of the war that the iron-ore reserves in the United States are so huge that mining operations (so far as the available ore is concerned) can readily respond to an increased demand for ore. The great increase in ore output during 1915 and 1916 and the fact that there was only a very moderate rise in the price of ore compared with the extraordinary rise in the price of pig iron indicate the accuracy of the prediction. At present the chief limitations to output of iron ore in the Lake Superior region are those imposed by shortage of labor and of transportation facilities. Notwithstanding the great drain on the iron-ore reserves new discoveries of ore have practically kept pace with production, so that there is as much ore known to be available as at the beginning of the war. This enlargement of known reserves is due largely to exploration work on the Cuyuna range, in Minnesota. In the summer of 1916, when the season for open-pit mining and shipping of iron ore was at its height, strikes among mine and dock laborers threatened seriously to curtail output and shipments, but a firm hold on the situation by the mining companies, coupled with a disposition to share profits with employees, averted serious or protracted trouble and made possible a record output of iron ore. The Lake transportation situation was further aided by high water and generally favorable weather, and there was good team work between the Lake fleet and the railroads at both ends of the chain. It has been freely predicted, however, that the present railway equipment and vessel tonnage can not greatly increase the movement of Lake Superior ore.

In other iron-ore districts, such as the Adirondack region, southeastern New York and northern New Jersey, and the Birmingham district, there was also much activity. These districts are relatively small, and their output could not have been increased in so large a proportion from existing mines, which are largely underground, had not the output of 1915 been only about normal or less than normal. In these and other small districts many long inactive mines were reopened; in fact, almost every mine that contained available ore of present commercial grade was drawn upon, and if an iron-ore mine can not be made to pay under present conditions there seems little hope for its immediate future.

Blast furnaces on the Atlantic seaboard, when possible, draw their supplies of ore, in part, from Cuba, Sweden, Spain, Canada, and

[1] Iron Age, July 19, 1917, p. 149.

Chile. The resumption of traffic through the Panama Canal made possible the importation of Chilean ore and also the transportation of iron and steel products to the Pacific coast of North and South America, to the Hawaiian and Philippine islands, and to Japan. The shortage of vessels, however, has seriously handicapped this trade.

IRON MINING BY DISTRICTS.

The bulk of the iron ore mined in the United States is produced in certain well-defined districts, and statistics of production by these units are of interest in showing how each has responded to the quickened demand for ore since 1914. The Lake Superior district mined nearly 85 per cent of the total ore in 1916, and the Birmingham district about 7.9 per cent, or less than one-tenth as much as the Lake district. The Adirondack is the only other individual district that mined as much as 1,000,000 tons. The increase in production in the Lake Superior district approximated 40 per cent in 1915 and 36 per cent in 1916; the other districts showed increases anging between 6 and 55 per cent in 1916.

Iron ore mined in the United States, 1913–1916, in gross tons.

	1913	1914		1915			
		Quantity.	Increase or decrease (percent).	Quantity.	Increase or decrease (percent).	Quantity.	Increase (percent).
Lake Superior (Minn., Mich., Wis.)	52,377,362	33,540,403	−36	46,944,254	+40	63,735,088	36
Birmingham, Ala	4,602,573	4,282,556	− 7	4,748,929	+11	5,976,018	26
Chattanooga (Tenn., Ala., Ga., N. C.)	708,619	432,006	−39	539,024	+25	836,623	55
Adirondack, N. Y	1,214,704	544,724	−55	699,213	+28	1,077,638	54
Northern New Jersey and southeastern New York	451,453	541,084	+20	644,493	+19	683,150	6
Other districts (south, central, and western)	2,625,726	2,098,988	−20	1,950,577	− 7	2,859,155	47
	61,980,437	41,439,761	−33	55,526,490	+34	75,167,672	35

FOREIGN TRADE.

Comparatively little iron ore is imported into the United States—only 1,000,000 to 2,000,000 tons a year, or about 2 to 3 per cent of the quantity annually mined. Moreover, the exports of iron ore nearly offset the imports, so that the United States is at present self-sufficient so far as the supply of iron ore is concerned. Such ore as has been imported in recent normal years has come mainly from Cuba, Newfoundland, Canada, Spain, and Chile. Supplies from the United Kingdom, Germany, the Netherlands, and Belgium were almost wholly interrupted in 1915 and 1916, and it is probable that the imports from Newfoundland, which diminished greatly in 1914 and ceased altogether in 1915, have been diverted to England or used at home. Supplies from Canada, however, arrived in increased volume in 1915 and 1916, largely from the Canadian ranges in the Lake Superior district.

It is possible to import high-grade iron ores such as are received from foreign countries for use along the Atlantic seaboard, if there is no interference with shipping and when ocean freights are low and there is no tariff on the ore. Even under these favorable conditions, however, foreign ore rarely gets beyond the tidewater furnaces. Although the United States possesses supplies of iron ore sufficient for normal demands and for many years of war needs, both European and American, present economic conditions render it practicable to import ore, especially from Cuba and South America. Iron ore forms the basis of the largest manufacturing industry in the United States. The profits to both capital and labor are derived from the manufacture and sale of iron and steel products rather than from iron-ore mining; therefore, so long as the United States can utilize cheap ores from Latin America and export to those countries, as well as to Europe and the Orient, fabricated iron and steel goods, there is reason to favor continued importing of iron ore. Moreover, as little good coal is known to occur near the largest deposits of iron ore in South America it may never be feasible to establish the manufacture of iron on a large scale on that continent. South American iron ore will thus find a market either in Europe or in the United States, and whatever part of it is commercially available to the United States should serve two important purposes if sold here, namely, in increasing trade between the United States and South America and in conserving the ore supplies of the United States.

The quantity of iron ore exported from the United States in recent years has only slightly exceeded 1,000,000 tons in any year, and the largest imports have been only a little over 2,500,000 tons.

A comparison between the quantities of iron ore mined in the United States and those imported and exported in the last five years is given in the following table:

Iron ore mined, imported, and exported in the United States, 1912–1916, in gross tons.

Year.	Mined.	Imports.	Exports.
1912	55,150,147	2,104,576	1,195,742
1913	61,980,437	2,594,770	1,042,151
1914	41,439,761	1,350,588	551,618
1915	55,526,490	1,341,281	707,641
1916	75,167,672	1,325,736	1,183,952

The imports of manufactured iron and steel (not including ferro-alloys) into the United States in the last three years have not varied greatly and are small in comparison with the exports, which have increased enormously, as shown in the following table:

Value of iron and steel products imported and exported in 1914, 1915, and 1916.[a]

	Imports.	Exports.
1914	$11,703,491	$65,988,280
1915	9,122,108	153,626,753
1916	11,098,607	362,524,715

[a] Compiled from records of Bureau of Foreign and Domestic Commerce, Department of Commerce.

A graphic comparison of domestic production and consumption of both iron ore and pig iron is shown in figure 4.

GEOGRAPHIC DISTRIBUTION OF IRON-ORE DEPOSITS.

The major features of the distribution of iron-ore deposits in the United States are now well known, and most of the ore-bearing districts that are advantageously situated with respect to transportation facilities, fuel supplies, manufacturing centers, and markets have been studied in more or less detail by the United States Geological Survey or by State organizations, including tax commissions, so that estimates of ore tonnage are available. Future general work in the less well-known areas and more detailed work in the better-known areas by both public and private agencies will probably increase rather than decrease the tonnage apparently available.

The locations of the principal deposits of iron ore in the United States are too well known to need extended description here. Twenty-eight States are regular producers of iron ore, and several others contain deposits of value. The States in which commercially important deposits of iron ore occur may conveniently be grouped into six geographic divisions, as shown in the following list, in which the varieties of ore found in each are also indicated:

1. Northeastern States: Massachusetts, Connecticut, New York, New Jersey, and Pennsylvania. Magnetite, hematite, and limonite.
2. Southeastern States: Maryland, the Virginias, Tennessee, North Carolina, Georgia, and Alabama. Hematite, limonite, and magnetite.
3. Lake Superior States: Michigan, Wisconsin, and Minnesota. Hematite, limonite, and magnetite.
4. Mississippi Valley States: Ohio, Kentucky, Iowa, Missouri, Arkansas, and eastern Texas. Limonite, hematite, and siderite.
5. Rocky Mountain States: Idaho, Montana, Wyoming, Colorado, New Mexico, Utah, and Nevada. Hematite and magnetite.
6. Pacific States: Washington and California. Magnetite and hematite.

The Lake Superior region is by far the most productive of these divisions and is followed in order by the southeastern and north-

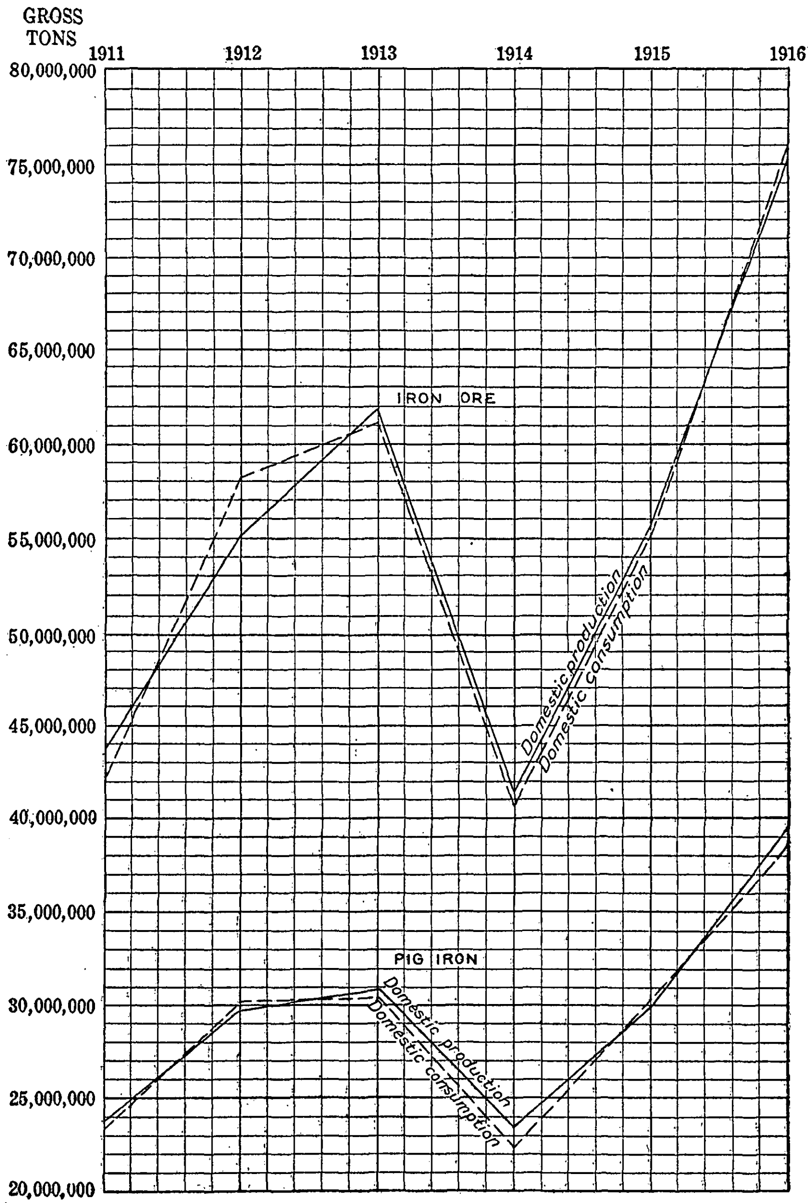


FIGURE 4.—Domestic production and consumption of iron ore and pig iron, 1911-1916.

eastern divisions; the Mississippi Valley and western divisions are at present of minor importance, although it is probable that Texas, California, and Utah are destined to become large producers of iron ore.

IRON-ORE RESERVES.

The following data on estimated tonnages of iron ore in the United States and in other countries bordering the Atlantic Ocean have for the most part been published by Eckel,[1] although arranged somewhat differently here:

Estimated tonnages of iron ore.

	Minimum.	Maximum.
UNITED STATES.		
Northeastern States	300,000,000	600,000,000
Southeastern States	2,000,000,000	2,750,000,000
Lake Superior States	2,000,000,000	2,500,000,000
Mississippi Valley States	600,000,000	1,000,000,000
Rocky Mountain States; Pacific States	300,000,000	700,000,000
	5,200,000,000	7,550,000,000
FOREIGN COUNTRIES.		
Newfoundland, Canada, Mexico, and Cuba		7,000,000,000
South America		8,000,000,000
Europe		12,000,000,000
Total tonnage on three continents bordering Atlantic Ocean		34,550,000,000

These recent estimates credit to the United States between 5,000,000,000 and 7,500,000,000 tons of iron ore of present-day commercial grade, of which about one-third is in the Lake Superior district. It thus appears that the United States possesses more than one-fifth of the available supply on three continents bordering the Atlantic Ocean.

Immense as this quantity may seem at first glance, it is not sufficient to prolong production for many decades if the rate of increase in consumption of ore that has prevailed thus far is maintained. The draft on the ore reserves of the Lake Superior district is relatively much heavier than on those of the other districts, on account of the possibility of open-pit mining on the Mesabi and Cuyuna ranges and the low cost of transporting the ore to coal fields. The Lake district normally produces over four-fifths of the iron ore mined in the United States, and it has been estimated that if this proportion and present rate of increase are both maintained the known ore reserves of present commercial grade in the United States portion of the Lake Superior district can not last much beyond the year 1930.[2] There are certain factors, however, that indicate the possibility of a considerable prolongation of the life of the Lake Superior iron-ore supplies, as well as of those of the whole United States. If ore consumption should continue at the present rate, with no further increase, the estimated reserves of present commercial grade in the United States would probably be sufficient for 150 years.

[1] Eckel, E. C., Iron ores, pp. 381-397, McGraw-Hill Book Co., 1914.
[2] Idem, p. 355.

IMPORTANCE OF CONSERVING IRON ORE.

The conservation of the iron-ore supplies of the United States, the discovery of new supplies, and the development of methods for rendering supplies of low-grade ore available are vital to the maintenance of the industrial independence and supremacy of this country, notwithstanding the apparent abundance of the supplies at present available, for, as has been pointed out, the reserves of high-grade iron ore now convenient of access are rapidly becoming depleted.

Certain important factors that will aid in prolonging the life of the iron-ore reserves of the United States may be summarized as follows:

1. The steady accretion to the permanent supply of metal and the consequent reduction in rate of increase of production (waste of war not taken into consideration).
2. The adoption of methods of conservation of ore and metal.
3. The increase in imports of ore from Cuba and South America, whose deposits must logically be regarded as a portion of the immediately available reserve, as such ores can be used most profitably and economically in the United States.
4. The further discovery of iron-ore deposits in the Western Hemisphere.
5. The possibility of metallurgic improvements that may enable pig iron to be derived economically from low-grade ores, and the solution of metallurgic problems, including that involving the utilization of titaniferous iron ores, of which there are large deposits not now available
6. The increase in the price of pig iron, which will bring lower grades of iron ore into the market, thus vastly increasing the tonnage of reserves available.

IRON AND STEEL MANUFACTURE.

Any discussion of the ability of the United States to continue to furnish iron and steel to her allies in Europe at the same or a greater rate than was maintained in 1916 and at the same time to meet the superimposed demands of war on the part of this Nation itself must take into consideration many factors bearing on the iron and steel making capacity of the country. At the outbreak of the war the iron and steel industry was operating on a subnormal scale, and consequently the manufacturing capacity was in excess of requirements. Some of this excess capacity was, of course, represented by antiquated equipment that could not be put into shape for resumption of operations on short notice. The excess capacity at the opening of the war was greater in blast furnaces than in steel furnaces, so that one of the first effects of the war was to stimulate the building of new steel furnaces. According to the Iron Trade Review,[1] the steel-making capacity at the beginning of 1915 was estimated at 37,500,000 tons, at the beginning of 1916 at 39,000,000 tons, and on January 1, 1917, at 43,000,000 tons, and it is expected that by January 1, 1918, it will amount to 48,000,000 tons. Thus there will have been an increase in three years of 10,500,000 tons, or 28 per cent, in steel-making capacity. The increase in capacity for basic-process steel is estimated to be about one-third greater than that for the acid process. The pig-iron capacity is estimated to have been more than 39,000,000 tons at the beginning of 1916 and to have been brought up to 40,000,000 tons at the beginning of 1917, but the prospective increase in blast-furnace capacity for 1917 is larger than for several years and will tend to close the gap between steel-making and pig-iron producing capacity, which has been becoming too wide.

The iron and steel making capacity at the end of 1917 will be none too large, judged by present and prospective demands, and probably it will not be large enough to fill orders promptly. The present excessively high prices are sufficient indication that the manufacturing capacity of the country is wholly absorbed. As to still further expansion there are of course limitations other than the demands for iron and steel. The capital involved in the iron and steel industry is so vast that ordinarily the future has to be taken seriously into consideration in planning new plants or additions to old plants. Wartime demands and prices, however, have upset many precedents and have encouraged many increases in plant capacity irrespective of the consideration whether or not they might prove excessive after the war. This has been particularly true of concerns whose profits have been great enough to pay off back indebtedness and pay for the additions to their plants within a year or two of their construction. In looking to the future the optimist has seen a demand heavier than normal after the war. Several factors in the domestic situation have appeared encouraging, such as the needs of the railways, of building construction, of the automobile industry, and of shipbuilding. Railway and general building and improvement work, except where urgently needed, is usually postponed in times of high prices and uncertain deliveries, but the longer these industries are deprived of supplies through such conditions the greater the flood of orders that will be released when conditions once more approach normal. Foreign trade with South America and the Orient is expected to grow, and European trade in the necessities of peace is expected to be augmented after the end of the war. The entry of the United States into the war and the

[1] Have we too many steel furnaces? Iron Trade Rev., Jan. 4, 1917, p. 47.

demands of this Government for iron and steel of course once more raise the question whether further increases in capacity will be absolutely needed on that account. Certain large steel makers have patriotically assured the United States Government that they would furnish the steel needed for the war at prices very much below those current in the spring of 1917. This fact in itself may deter further increase in capacity, inasmuch as profits from such work sufficient to pay for the increase within a few months will not be in sight. It is probable also that the Government orders will be placed slowly and will not exert a sudden strain on manufacturing capacity.

There are also certain factors which will affect the manufacturing capacity just as vitally as insufficient equipment. Among these are limitation of supplies of coke and other fuel and of ore, due to insufficiency of transportation facilities and of labor, as well as shortage of labor at the steel mills. Some observers of the situation feel that the capacity for making crude metals will probably prove sufficient, but that the real problem lies in the ability to fabricate the special articles used in warfare, as well as in the industries expanded by war demands.

ESSENTIAL GEOLOGIC AND METALLURGIC STUDIES.

Interest in the question of the duration of iron-ore reserves has already been awakened. Estimates of such reserves based upon incomplete field work of the United States Geological Survey show that, though relatively great, the reserves are not unlimited, and statistical canvasses extending back for many decades show the immense increases in consumption of ore, so that data are available from which calculations may be made with reference to the probable life of the deposits. Much may yet be done to further the work of iron-ore conservation and efficient utilization. The United States Geological Survey should continue both reconnaissance and detailed geologic work on the deposits of iron ore and manganiferous iron ore within the country and also keep more closely in touch with commercial developments, both prospecting and mining, so that at any time up to date information may be readily available concerning the status of the iron-ore reserves. Statistical data should be gathered from year to year that will show accurately the variation in the metallic content of the ore as mined, the quantities of ore of different grades that are mined, and thus the general trend during a series of years. Technologic studies should be made, both under Government auspices and by mining companies, bearing upon the decrease of wastage in iron-ore mining, upon the possibility of increasing the percentage of extraction in mining, and upon the problems of beneficiating iron ore, through processes by which enormous supplies of ore of grades too low to be utilized under present conditions may be made available. Here also is an opportunity for the invention or improvement of metallurgic processes by which pig iron may be made commercially from ores of lower grade than at present used and from titaniferous ores, and by which ores may be smelted electrically in regions where cheap water power is available but good coal is scarce.

BARIUM AND STRONTIUM.

By James M. Hill.

BARIUM.

USES.

Barytes (barite or barium sulphate) is used chiefly in making mixed paints, in which white, ground, and water-floated barite is employed as a pigment. Ground barite is also used in the rubber industry and to some extent by the makers of heavy glazed paper and ink. Lithopone, a chemically prepared white pigment consisting of about 70 per cent barium sulphate and 30 per cent zinc sulphide, is one of the chief constituents of the "flat" wall paints so extensively used in office buildings and hospitals, replacing the less desirable paper and calcimine wall finishes.

Since the beginning of the war a barium chemical industry has been established in the United States to supply barium carbonate, nitrate, chloride, chlorate, hydrate, and binoxide, which were formerly imported largely from Germany. In 1915 this industry consumed 10 per cent of the output of domestic barite, but the consumption in 1916 was apparently somewhat larger. The barium chemicals have a wide variety of applications, perhaps the most important of which are the use of barium binoxide in the preparation of hydrogen peroxide, that of barium chloride as a water softener, and that of various salts in the manufacture of optical glass.

SUPPLY.

Barytes (or, as it is called in Missouri, tiff), as shown by a recent report of the United States Geological Survey,[1] is mined principally in the Southeastern States, particularly southeastern Missouri, northwestern Georgia, east-central Tennessee, central and western Kentucky, northeastern Alabama, southwestern North Carolina, northwestern South Carolina, and southwestern Virginia. The production of 108,547 short tons in 1915 was over twice as large as that of

[1] Hill, J. M., U. S. Geol. Survey Mineral Resources, 1915, pt. 2, pp. 161–187, 1916.

1914, and in 1916 the output was again doubled. The value of the 1916 output was over $1,000,000—a figure never attained before. It is interesting to note that whereas Missouri has usually made a larger production than any other State, in 1916 Georgia mines produced nearly twice as much as Missouri mines. There are known deposits of barite in several of the Western States, and some of these deposits—notably in Colorado, Nevada, California, and Alaska—were mined during 1915 and 1916.

Prior to the war a considerable part of the crude barite used on the Atlantic seaboard was imported from Germany, chiefly because of the cheaper water transportation, with which the American producers could not compete. Since this supply has been shut off, although the domestic requirements have more than trebled, the domestic mines have supplied all the demands and appear to be capable of meeting all future requirements.

The only commercial deposit of witherite (barium carbonate) known to the Geological Survey in the United States is near El Portal, Mariposa County, Cal.

STRONTIUM.

USES.

Strontium salts, chiefly the nitrate, are employed to make "red fire," which is of wide use at this time not only for signal lights on battle fronts but for railway signals to promote the safe handling of trains at night. It is estimated that prior to 1914 about 2,000 tons of strontium nitrate was used annually in the manufacture of such "flares" or "Costen" and "Bengal" lights and fireworks. Since 1915 the demand has increased considerably.

SUPPLIES.

Before the war celestite (strontium sulphate) and strontianite (strontium carbonate) were imported from Germany, England, and Sicily. During 1914 and 1915 English celestite was obtained by manufacturers, but late in 1915 the exportation of strontium ores was embargoed by England. Strontium ores are known in the United States, the principal commercial deposits being in southern California, Arizona, Washington, and Texas. The Texas and Washington ores can be mined so as to produce high-grade celestite, and some of the Arizona and California celestite is of excellent grade. Some of the deposits in Arizona and California, however, are mixed with barite and calcite, which detract from their value. One deposit in southern California, now being worked, consists of good-grade strontianite, which is particularly desirable, as it is directly soluble in acid, whereas the sulphate must be roasted to sulphide before it is soluble.

Apparently United States manufacturers are now using domestic ores containing only 85 per cent of strontium sulphate, though they prefer not to use materials of lower grade than 92 per cent.

The United States Geological Survey has been instrumental in investigating and calling attention to available supplies and in bringing together, through correspondence and published information, the producers and consumers of barium and strontium ores.

MICA, MONAZITE, AND LITHIUM MINERALS.

By WALDEMAR T. SCHALLER.

MICA.

Mica is valuable on account of its cleavage, flexibility, elasticity, and nonconductivity of heat and electricity, a combination of properties in which it is unsurpassed by any other abundant mineral. The extensive employment of mica in electric appliances requires a large quantity in the aggregate, although the quantity used in a lamp socket, for example, is extremely small.

Much mica is ground for use in decoration and for insulation. About 90 per cent of the mica produced in the United States is scrap, which is eventually ground into powder, but the remaining 10 per cent is sheet mica, worth from five to seven times as much as the scrap. Sheet mica has become a necessity in everyday life, and much of the ground scrap mica is, in a way, a by-product of the manufacture of sheet mica, consisting largely of the trimmings resulting from the cutting of the sheet mica into regular forms.

Sheet mica is found in many countries. It has been produced in the United States, Canada, Brazil, Argentina, German East Africa, Transvaal, British Nyassaland, Natal, Madagascar, India, Ceylon, Australia, China, and Japan. Small quantities are also mined in Mexico, Guatemala, Norway, Russia, southwestern Africa, and Chosen, but at least 97 per cent of the annual output of sheet mica is mined in the United States, Canada, and India. The United States produces about 60 per cent and India about 30 per cent. The India mica, which has to be transported a considerable distance and is therefore well selected and trimmed before shipping, is of greater value, weight for weight, than the American mica. The value of the annual output in India is about 60 per cent of the total value of the world's production; that of the output in the United States is about 20 per cent.

The imports of sheet mica exceed the domestic output in both quantity and value. In 1916 more than $1,000,000 worth of sheet mica, unmanufactured and manufactured, was imported More mica is imported from Canada than from India, but the value of the India mica is greater. The mica from India comes both direct and through England.

The demand for mica in 1915 was brisk, and in the United States the average price of sheet mica, rough trimmed and cut, was 68 cents a pound, the highest since 1900. Since 1915 similar or slightly higher prices have prevailed.

The relation of imported to domestic mica is shown in the following tables:

Mica consumed in the United States, 1912–1916.

Year.	Quantity.			Value.		
	Domestic production (short tons).	Imports (short tons).	Percentage of domestic.	Domestic production.	Imports.	Percentage of domestic.
1912	3,650	1,166	76	$331,896	$755,584	31
1913	6,172	[a] 1,265	83	436,060	947,783	32
1914	4,008	[a] 611	87	329,956	629,484	34
1915	4,236	[a] 613	87	428,769	692,269	38
1916	4,866	[a] 856	85	594,391	1,071,356	36

[a] Estimated.

Until 1916 there was a slight, steady increase in the percentage of the total produced by the United States. The decline in the percentage for 1916, is, however, slight.

Sheet mica consumed in the United States, 1912–1916.

Year.	Quantity.			Value.		
	Domestic production (short tons).	Imports (short tons).	Percentage of domestic.	Domestic production.	Imports.	Percentage of domestic.
1912	423	995	30	$282,823	$748,973	27
1913	850	[a] 1,120	43	353,517	943,018	27
1914	278	[a] 409	40	278,540	625,396	31
1915	277	[a] 441	39	378,259	688,411	35
1916	433	[a] 675	39	524,485	1,067,936	33

[a] Estimated.

Beginning with 1914, there was a considerable decrease in the amount and value of unmanufactured mica imported, but a considerable increase in the imports of cut or manufactured mica.

The mica obtained in this country and from India is muscovite; that from Canada is phlogopite. For certain pieces of electric machinery phlogopite is preferable to muscovite, and deposits of phlogopite in New York and New Jersey are now being examined. The mica from these two deposits is of good quality and it is hoped that they will become commercial sources.

Is the dependence of the United States on foreign countries for sheet mica due to an inherent deficiency in the domestic supply of mica or to economic conditions that may have no direct bearing on the amount of mica available in this country? In other words, if the United States had to depend on its own resources for mica, could it supply the demand, irrespective of cost?

In the report on the production of mica in 1912 Sterrett[1] says: "The mica mines of the United States are capable of a large annual production and could be made to supply all but that small part of the domestic demand which calls for the softer Canadian amber mica." He states further: "The quality of the best domestic mica as to transparency, color, cleavage, and flexibility is equal to that of the same variety produced in India and other countries." The conditions outlined for 1912 are the same to-day. The amount of mica produced could be very materially increased. However, the cost of operating mines in the United States is very large in comparison with the cost in India, where labor is cheap.

Much of the mica mined in the United States is obtained from deposits operated entirely by hand, and, especially in North Carolina, a good part of the output is obtained by farmers who work their deposits intermittently when the crops do not require their attention. Were a demand for mica to become imperative, and were the mica mined economically and with care (a valuable bunch of sheet mica can be easily ruined by careless use of a drill or pick), then the United States, already producing 60 per cent of the world's output of sheet mica, could easily produce enough to meet all its own demands. Possibly the further exploitation and development of the phlogopite deposits in New York and New Jersey will show that this country could become independent of the world with respect to mica.

It is understood that sheet mica has come to be of importance as a war mineral through its use abroad in making windows of masks worn for defense against asphyxiating gases, and for other uses where a transparent, noninflammable, nonshattering material is necessary, as in automobile goggles and in windows for armored cars.

MONAZITE.

The mineral monazite contains a variable but small percentage of thoria, which is extracted and sold in the trade as thorium nitrate. Upon ignition this nitrate is changed to the oxide or thoria, which glows intensely when heated and is used in the manufacture of incandescent mantles for gas lights. Monazite occurs throughout the world but forms only a very small fraction of 1 per cent of the rock containing it. On decomposition of this rock the monazite and

[1] Sterrett, D. B., U. S. Geol. Survey Mineral Resources, 1912, pt. 2, p. 1085, 1913.

other resistant minerals are not attacked chemically but remain unaltered and, being much heavier than the products of decomposition, are gradually but slowly concentrated in the residue from the broken-down rock. If the ocean encroaches on an area of such decomposed rock, the selective action of the sea waves will still further concentrate the heavier minerals along the beaches. River waters will likewise effect a concentration of the heavy minerals.

In both North Carolina and South Carolina such river deposits were first worked about 1887 and soon yielded large quantities of monazite sand, the production in 1895 exceeding 1,500,000 pounds. At this time monazite from the rich coastal deposits of Brazil entered the market, and the domestic production fell to almost nothing, that for the two years 1896 and 1897 being worth only $3,480. The price of thorium nitrate, which was about $200 a pound in 1895, when the production in the Carolinas reached its maximum, was rapidly lowered to about $7 a pound in Europe in 1900. During the next new years it rose to about $11 a pound, and the increase in price together with a world-wide search for additional deposits of monazite sand, served to revive the industry, until in 1905 over 1,000,000 pounds of monazite sand was again produced in the Carolinas. Much of this output was exported to Germany. In 1906 and again in 1910 the price of thorium nitrate was considerably reduced, and in 1913 it was selling in this country at $2.60 a pound. At this low price it became unprofitable to mine monazite sand wherever the cost of mining was high. After 1905 the domestic production gradually decreased, and since 1911 it has been inappreciable.

In 1909 monazite sand was discovered in Travancore, India, and soon large amounts were produced. The Carolina sand has had to compete with these deposits and others in Brazil, which could be mined very cheaply. Most of the Brazilian sand and all of the India sand was exported to Germany until the beginning of the European war. Since then most of the sand has been sent to this country, which imported nearly 2,500,000 pounds of monazite sand in 1916. With this increase in imports of monazite sand there has been a steady decline in imports of thorium nitrate, from 119,044 pounds in 1913 to 909 pounds in 1916. In other words, the United States is manufacturing its own thorium nitrate, chiefly from sand imported from Brazil and India. The price of thorium nitrate has gradually increased since the war and now is about $8 a pound, or three times as much as in 1913. This advance in price has again stimulated the domestic production of monazite sand, and small amounts were produced in 1915 and 1916.

There is still an abundance of monazite sand in the Carolinas, but the Carolina deposits can not be worked extensively in competition with foreign sand. As the United States consumes about one-fourth of the thorium nitrate used in the world, it requires a yearly production of about 2,000,000 pounds of monazite sand (90 per cent monazite containing 5 per cent thoria. Even in its most prosperous times the domestic output did not reach that figure. Whether such a domestic production could be sustained year by year if all imports were cut off can not be told. The Carolinas, however, could produce enough monazite sand to make this country independent of other sources for several years at least, and if the ashes of broken mantles were conserved by consumers, enough thorium nitrate could be obtained from domestic sources to serve for some time.

The factors that have prevented a thorough test of the extent of the domestic deposits in recent years are the better quality and cheapness of the imported foreign sands. Both the Brazilian sand and that of India contain a higher natural concentration of monazite and a higher content of thorium oxide than the American sand, the sand from Brazil averaging about 6 per cent thoria and that from India about 9 per cent. The cheapness of labor and transportation in these foreign countries has also deterred domestic exploitation. The market price of thorium nitrate is a good indicator for domestic production of monazite sand, for only at a high price for this manufactured salt can the domestic sands be profitably worked. The importation of large quantities of foreign sand rich in thoria prevents a very high price being paid for thorium nitrate.

LITHIUM MINERALS.

The chemical products derived from lithium minerals can not be considered necessary for every-day life. Such products, however, find several applications, especially in military uses, in which they serve a useful purpose. Lithium minerals are produced in this country in varying amounts up to 1,000 tons a year.

The United States has been the largest continuous producer of lithium minerals (spodumene, lepidolite, and amblygonite) and has in the past exported a considerable quantity of the yearly output. Lithium minerals have also been mined in Germany, Austria, Sweden, France, Australia, and Spain, but the amount produced in this country is probably larger than that in the other countries combined. As the domestic production has been ample to satisfy the needs of this country, and the crude minerals have been also treated here, the European war has not induced special efforts for larger development of the deposits, and there has been practically no change in the production of lithium minerals since 1913.

California and South Dakota have furnished all the lithium minerals produced in this country. Such minerals have been found abundantly in Massachusetts and in Maine, but at present prices the deposits in these two States have not been exploited. The amount of lithium minerals still available is very large, and if an increased demand were to arise, the United States could supply many times the present output for a long time to come.

ZINC.

By C. E. Siebenthal.

Early in the European war the larger part of the zinc-smelting capacity of Europe was either destroyed or in the hands of the Teutonic belligerents. About 75 per cent of the spelter output of Europe in 1913 was produced by Belgium, Germany, and Austria. Both the zinc smelters and the zinc deposits of Germany are in the Rhenish-Westphalian and Silesian districts. The Belgian smelters were soon captured by the Teutonic allies. Under these circumstances the entente allies had to depend for spelter almost wholly upon the zinc smelters of the United States.

For some time before the war zinc-smelting capacity in the United States had been increasing faster than the consumption, as shown by the increase in spelter stocks at smelters, there being 40,659 tons in stock at the beginning of 1914 and 64,039 tons at the middle of the year, just before the war began. These stocks and the excess smelting capacity were immediately available to supply foreign demands, and at once the smelters began large exports of spelter and sheet zinc to Europe.

Except for a short flurry after the declaration of war the price of spelter during the remainder of 1914 was not much higher than it had been during the first half. As a consequence there was little increase in production or smelting capacity, the number of retorts being 111,458 at the end of 1913 and 115,114 at the end of 1914, with 10,192 retorts in process of building or contemplated. During the first half of 1915 the spelter stocks at smelters became exhausted and, the demand exceeding the production, the scarcity was manifested in rising prices, which culminated June 5 at 26.5 cents for prime western spelter and a correspondingly higher price for high-grade spelter. Then began a period of feverish activity in smelter building and renovating. Small, old, abandoned, coal-fired zinc smelters in Missouri and Kansas were rebuilt and fired up, and several gas smelters in Kansas, practically abandoned from lack of fuel, obtained small warm-weather supplies of gas and started smelting. New gas smelters were built in record time in Oklahoma, new producer-gas smelters were rapidly constructed in Pennsylvania and Illinois, and additions were made to smelters already in existence. The number of retorts at the end of 1915 was 156,568, besides 49,612 under construction or contemplated, and in addition a daily capacity of approximately 200 tons for electrolytic spelter was in operation, under construction, or planned. By the middle of 1915 the spelter capacity of the country had been developed to a point where it supplied current needs and allowed the accumulation of what the entente allies considered to be ample supplies of munitions for the military operations of that year. This condition, together with the coordination of purchasing agencies for the allies whereby they no longer competed with one another in the purchase of spelter, caused a great decline in the price, which dropped from 26 cents to less than 12 cents in one month.

The experience of 1915 showed, however, that the reserves of munitions were nowhere near sufficient—in fact, it is reported that the principal offensive operation was cut short by their exhaustion. Preparations were therefore begun to lay in an adequate supply for the drive of 1916 and for reserves along the extended battle line. Meantime, many less advantageously situated plants found spelter making unprofitable at 12 cents under war conditions and were closed wholly or in part. Under these circumstances the price of spelter gradually rose again and in February, 1916, reached 21 cents. This rise stimulated more smelter building and by the middle of 1916 the total number of retorts had risen to 196,640, besides 24,812 retorts under construction or contemplated. In the meantime other countries had been increasing their zinc-smelting capacity, notably England and Japan. Early in 1916 the price of spelter began to weaken, and between the middle of April and the middle of July it had fallen from around 19 cents to about 9 cents. Through the last half of 1916 and the first five months of 1917 the price of spelter ranged between 8 and 13 cents. In spite of the decline in prices smelter building kept up, and the number of retorts at the end of 1916 was 219,418, and about 18,000 additional retorts were in process of building or contemplated.

The following table shows the increase in spelter production and in exports of zinc and brass and their manufactures by six-month periods during the war. The first war demands were for spelter and sheet zinc, the exports of which averaged between 10,000 and 13,000 tons a month up to the middle of 1916. During the last half of 1916 and the first three months of 1917 the exports were nearly doubled, averaging over 21,000 tons monthly. The exports of brass grew rapidly, being four times as large in the last six months as they were in the first six months of 1915, and almost doubling the monthly rate, in the first three months of 1917. The exports of manufactures of zinc and brass and also of cartridges grew rapidly, being now about seven times as great as in the first six months of 1915. The startling quantities of munitions exported in recent months were doubtless required in preparation for the offensive now in progress. It is reported that relatively three or four times as much heavy ammunition is being used on the western front this year as was used in the Somme offensive in 1916. The fact that this great consumption of munitions has had no more effect on the price of spelter than to raise it to 13 cents for a short time in November and December, 1916, seems to indicate that the zinc-smelting capacity has been brought up to the point where it is able to meet every demand. In fact, it has been suggested that there has been some overproduction of spelter and that stocks have probably accumulated. Be that as it may, it is not likely that there can, under present conditions, be any further material decline in the price of spelter, for that would probably so reduce the output of sphalerite concentrates from the sheet ground of the Joplin region as to react upon the price of spelter, causing it to rise again.

Spelter produced in United States and zinc and brass exported, 1914–1917.

	Spelter produced (short tons).	Exports.					
		Spelter and sheets, domestic, foreign, and drawback (short tons).	Zinc dross (short tons).	Brass (short tons).	Old brass (short tons).	Value of manufactures of zinc and brass, including cartridges.	Total value of exports of zinc and brass.
1914.							
January-June	175,058	2,878	286	1,542	6,774	$3,841,237	$6,337,416
July-December	177,991	72,490	2,249	2,015	3,552	6,712,225	17,162,383
1915.							
January-June	216,532	70,326	2,932	18,126	4,331	25,070,587	44,088,252
July-December	272,987	61,306	1,235	15,010	456	43,154,056	70,479,204
1916.							
January-June	316,452	78,204	28	51,543	1,284	123,135,226	177,343,769
July-December	351,004	128,163	20	70,723	2,194	174,210,117	253,456,204
1917.							
January-March	....	64,049	1,909	63,464	1,252	83,821,780	138,670,854

Soon after the beginning of the war the United States Geological Survey made the statement[1] that the United States would have "the opportunity to furnish the major part of 222,000 tons of spelter a year as long as the war lasts." Though part of the zinc exported has been in the form of brass, the total exports of zinc in all forms for the first three years of the war will be found to average about 220,000 tons a

[1] U. S. Geol. Survey Press Bull. 181, August, 1914.

year. This quantity is exclusive of the zinc in manufactures of zinc and brass, including cartridges, which in value have averaged nearly $200,000,000 a year but whose zinc content is not known. At the rate of increase shown in the last half of 1916 and since maintained the exports for the remainder of the war promise to be much larger.

The zinc reserves of the country have shown themselves to be equal to all demands made upon them. In fact, the production of zinc ore has been so large that further decline in ore prices with resultant demoralization of the domestic zinc-mining industry can be prevented only by a material increase in the demands for spelter or by a lessened supply of foreign ore. An increase in the demand for spelter seems probable, as has been indicated above, and imports of zinc ore may decrease also, if shipments from Spain and Australia are interfered with by submarines, or if the Australian concentrates are diverted elsewhere, or if shipments of zinc ore from Mexico are prevented. The zinc content of zinc ore imported in 1915 amounted to 57,669 short tons and in 1916 to 148,147 tons. Mexico and Australia each furnished about one-third of the imports. The imports of zinc ore for the first four months of 1917 indicate a falling off of 40 per cent from the average monthly imports in 1916.

The chief zinc-producing regions in the United States are the Joplin district of Missouri, Kansas, and Oklahoma, furnishing about one-fourth of the country's zinc output; the Franklin Furnace district of New Jersey, and the Butte district of Montana, each yielding about one-fifth of the total supply; the upper Mississippi Valley district of Wisconsin, Iowa, and Illinois; the Leadville district of Colorado, and the Coeur d'Alene district of Idaho, each producing between one-tenth and one-twentieth of the total.

NITRATES.

By Hoyt S. Gale.

Nitrogen for use in manufactures and in agriculture is supplied principally in the form of nitrates, and as these salts, or the nitric acid derived from them, constitute the basis of practically all explosives, they are absolutely essential also to warfare. As they are among the chief salts used in chemical fertilizers an adequate supply of them affects directly the quantity and the quality of the food supply.

Nearly all the sodium nitrate marketed is obtained from extensive deposits in the desert region of northern Chile. Commonly a few thousand tons of potassium nitrate is imported annually from India, where it is artificially produced in "saltpeter plantations." Calcium nitrate obtained in Norway by artificial fixation of the nitrogen of the atmosphere has also been listed among the fertilizer materials marketed in this country. The United States has been the largest purchaser of Chilean nitrate since the German market has been cut off. Just after the outbreak of the European war the Chilean nitrate industry experienced a severe depression, which has, however, been followed by gradual recovery. The cost of production at the mines has risen considerably, owing largely to the increased cost of labor and the scarcity and high price of fuel. The coal used for refining the nitrate has been obtained principally from Wales as return cargo in the nitrate vessels. Fuel oil from California is also used.

At present the dearth of shipping facilities and high freight rates have considerably increased the price of the nitrate in the countries to which it is exported.

Nitrate of soda exported from Chile, calendar years 1912–1915, in short tons.[a]

1912	2,748,124	1914	2,035,707
1913	3,018,469	1915	2,230,054

A general idea of the importance of nitrates in this country may be obtained from the statistics of imports, which practically represent the domestic consumption, there having been no domestic production

[a] The figures for 1912-1914 are from Anuario estadístico de la República de Chile, Minera y metalurgía, vol. 7, 1914, p. 67, Santiago de Chile, 1915. Those for 1915 are from Supplement to Commerce Repts., Ann. Ser., No. 41b, p. 5, Nov. 10, 1916.

of consequence. The rated values given with import returns, which perhaps represent cost exclusive of freight, are lower than the usual market quotations. For instance, the normal New York quotations for sodium nitrate, 95 per cent pure, ranged from \$44 to \$52 a short ton in 1912 and from \$44.40 to \$52.40 in 1913. At the end of 1916 or early in the spring of 1917 sodium nitrate was quoted at \$75 a ton in Atlantic ports.

Nitrate salts "entered for consumption" in the United States, 1912–1916.[a]

Calendar year.	Sodium nitrate.		Potassium nitrate.	
	Quantity (short tons).	Approximate rated value per ton.	Quantity (short tons).	Approximate rated value per ton.
1912	545,192	\$30.00	3,256	\$62
1913	686,404	31.50	4,826	54
1914	611,218	25.00	1,115	67
1915	863,103	26.50	3	117
1916	1,365,962	28.00	5,769	263

[a] Figured from statistics of the Department of Commerce.

The import figures show a war-time stimulus, the normal annual domestic consumption of about 600,000 tons of sodium nitrate increasing to more than double this amount in 1916. Of this large increase between 100,000 and 200,000 tons is believed to be in storage as a reserve for the time when access to a foreign supply may be cut off. The remainder of the increase, probably 600,000 tons, may be assumed to have gone into munition manufacture, chiefly for export.

The amount of nitrates consumed in fertilizers is not known exactly, but about 280,000 short tons (250,000 long tons) of sodium nitrate was used in 1916 for direct application to the soil as fertilizer. It is said to be applied chiefly as a top dressing, by itself, to promote or hasten growth at certain seasons, usually in the spring, after the crop has made a start.

A very important use for sodium nitrate is in the manufacture of sulphuric acid by the chamber process. In this process, by which the greater part of the acid of low gravities produced in this country is made, the nitric acid is required for the oxidation of the sulphurous gases to sulphuric form. The weight of sodium nitrate used in this way is estimated to be about 5 per cent of the weight of the sulphur consumed to make the sulphuric acid. The production in 1916 of 4,500,000 tons of sulphuric acid of strengths less than 66° Baumé therefore required 75,000 long tons (nearly 85,000 short tons) of sodium nitrate.

There are many other industrial uses of nitrates for which, at present, accurate statistics are not available. The following estimated summary is therefore given in general terms:

Sodium nitrate consumed in the United States in 1916.

	Quantity (short tons).	Approximate percentage.
Explosives	600,000	45
Fertilizers	280,000	20
Manufacture of sulphuric acid	85,000	5
Miscellaneous, including stocks in storage	400,000	30
	1,365,000	100

Unfortunately there is in the United States no natural source of nitrate salts that seems to promise an important supply. Small deposits yielding remarkably rich specimens have been found in many places throughout the country, and during former war times saltpeter for use in making gunpowder was obtained by crude leaching methods from minor deposits in caves. The total amount obtained in this way was probably not very large, and in comparison with the greatly increased rate of consumption in explosives and industrial uses the supply obtainable from such sources would be at best an almost negligible contribution for present needs, even on the assumption that these small deposits would be worth working again as they were in the past, an assumption which is probably not warranted. This subject has been carefully studied by the United States Geological Survey in the hope of finding some source of sufficient promise to justify exploitation, if only as a war-time emergency, but the conclusions have been essentially negative.

There are in several of the Western States considerable deposits of nitrate-bearing earths or clays which have been found to contain in places from 2 to perhaps 5 or 6 per cent of sodium nitrate, in conjunction with sodium sulphate and chloride, and it is conceivable that these deposits might be worked by leaching and some method of crystallization to separate the salts. These deposits are of very doubtful importance, however, on account of the difficulty in recovering a small percentage of nitrates by methods now in use or known. On the whole there is within the United States no known natural source of nitrates that can be counted on to furnish any considerable supply of the refined nitrate salts. This statement does not refer to the bacterial development of nitrates in soils through processes connected with cultivation and cropping, which is of course an important aid to agriculture but does not come within the scope of the present account of extractable nitrate salts.

The importance of the nitrate supply is recognized by an act of Congress approved June 3, 1916, which appropriated $20,000,000 to enable the President to make an investigation of the best, cheapest, and most available means for the "production of nitrates and other products for munitions of war and useful in the manufacture of fertilizers," by water power or any other means, and which authorized the President to construct, maintain, and operate the plants and equipment necessary to produce these materials. The product is to be used for military and naval purposes so far as it is needed, and any surplus may be sold for other uses.

The processes for fixation of atmospheric nitrogen that have been developed in a practical way may be classified as the arc processes, the Haber process, and the cyanamid process. The arc processes involve direct oxidation by means of the electric arc to form nitric acid and nitrates. These are fundamentally the simplest but are limited in application by the great amount of electric power required. Norway, with abundant water power, has been able to employ these processes successfully, but it seems doubtful if the power available in this country could be spared for use in this way. The Haber and cyanamid processes form other compounds of nitrogen, which, however, can be converted into nitrates by a further process. The Haber process consists in forcing gaseous nitrogen and hydrogen to combine under high pressure, a reaction being effected with the aid of a catalytic agent. This process yields ammonia which would have to be converted to nitric acid, at least in part, to supply munition requirements, but which could be used in agriculture by conversion into ammonium phosphate or sulphate. This process, together with one for obtaining ammonia from cyanamid, is used at present in the production of nitric acid for munition supplies and inorganic nitrogen fertilizer salts in Germany, and these industries are believed to have been developed to such a degree as to render that country entirely independent of outside sources of nitrates when the war requirements cease. The cyanamid process consists in the production of a compound of lime, nitrogen, and carbon, known as calcium cyanamid. It involves two main steps, each based on electric-furnace treatment but requiring only about one-fifth the power expenditure of the arc process. It is said that calcium cyanamid must be converted into ammonium salts to meet the requirements of nitrogen-carrying mixed fertilizer. An additional step would be necessary to convert the product to a nitric form.

By-product ammonia, derived from the production of coke and of illuminating gas, is an important source of combined nitrogen and is an available source for the production of nitric acid or nitrates. Such ammonia can be practically oxidized to nitrates, and the supply of this material is therefore available to relieve emergency requirements should other sources fail.

Thus it appears that measures are now being taken to insure the country a nitrate supply. As not all these measures would be immediately effective in case of unforeseen emergency, it is assumed that reserves have been accumulated which will tide over any temporary emergency that may arise.

LEAD.

By C. E. SIEBENTHAL.

WAR PRICES.

When the European war began lead was selling at slightly less than 4 cents a pound. A month or so later[1] the observation was made that "The effect of the war on the lead situation is as yet uncertain. One month of war has not disturbed the already low price of lead in the United States, but it would seem that the conflict must ultimately enhance the price." In October lead sold at 3½ cents, but a little later the price began to rise slowly, and the increase continued well on into 1915, presumably owing to purchases by the allies in preparation for operations in that year. The stocks of lead at the beginning of the war may have been large, for the refined lead produced in 1914 exceeded that in 1913 by 80,000 tons. Possibly because of the exhaustion of these stocks, the price in May and June of 1915 rose to 7 cents, coincident with the high point for spelter in that year, but soon dropped to 4½ cents. Then came the accumulation of munitions in preparation for the operations of 1916, and the price of lead gradually rose until in April, 1916, it reached 8 cents. This was followed by the usual decline, the price reaching 6 cents in August, and this in turn was succeeded by a rise in anticipation of operations in 1917, bringing lead to 12 cents at the present writing (June 18, 1917).

LEAD SUPPLIES.

The effect of the high prices has been to push production to the utmost. In the accompanying table the production of lead in this country from foreign ore and bullion is shown to have decreased materially from the quantity obtained in 1912 and previous years. This reduction is due to the internal dissension in Mexico, from which most of the foreign lead ore and bullion is imported, and has thrown a heavier burden upon the lead mines of the United States. This burden was partly met by an increase of 25 per cent in domestic production in 1914 and a further increase of 10 per cent in 1916, but

---

[1] Smith, G. O., Our mineral reserves: U. S. Geol. Survey Bull. 599, p. 22, 1914.

that supplies are not yet adequate seems to be indicated by the constantly rising prices. If, however, we are just now on the peak of one of these periods of high prices which seem to be synchronous with the periods of activity in military operations, it may be that a decline in prices will ensue, followed by a period of lower prices, thus indicating that the supply is in reality equal to the demand. That is a matter which can be determined only by the future trend of prices. Just at present, so far as prices are an indication, lead seems to be on a par with copper, aluminum, tin, iron, and manganese, the demand for all of which seems to be in excess of the readily available supply.

The lead-smelting furnace capacity of the United States has for several years exceeded the requirements and has in part been idle. When the war demands came on, this surplus furnace capacity was renovated and blown in. Two modern smelters were constructed—the plant of the Northport Smelting & Refining Co., at Northport, Wash., started in 1916 with four blast furnaces, and the Bunker Hill & Sullivan smelter at Kellogg, Idaho, with three blast furnaces which will be blown in soon. In addition the Empire Smelting & Refining Co. has rebuilt the plant of the old Luna Lead Co. at Deming, N. Mex., and has started with two lead blast furnaces. Any lack in lead supply is apparently not due to lack of smelting capacity.

Details of smelter output and lists of the lead-smelting plants in North America, together with the statistics of imports and exports and other data relating to the lead industry, will be found in the chapter on lead in the annual volume Mineral Resources of the United States, published by the United States Geological Survey.

The greatest gains in the production of refined lead have been made from ores derived from Idaho, Utah, and Missouri. Idaho has averaged 46,000 tons more of refined lead a year during the war than in the four years preceding it; Utah has averaged over 40,000 tons more, and Missouri 38,000 tons more. It is to these States that we must look for the larger increase during the remainder of the war, although gains will undoubtedly be made by all the lead-producing States under the stimulus of the present unprecedented high prices for lead. Added incentives to production are the high prices of silver and zinc and the improved metallurgic practice by which the zinc content of complex ores can be paid for instead of being penalized. Many old silver-lead mines in the Western States, which had been abandoned on account of the decline in the price of silver or on account of an increase in the amount of zinc in the ore taken out, are being reopened. Largely for these reasons Arizona made a good increase in lead output in 1916. The very productive mines in northeastern Oklahoma increased the output of lead from that State in 1916 and promise a much larger gain in 1917.

Moreover, the prospects just now seem good for increased imports from Mexico. The smelters at Matehuala and San Luis Potosi, in the State of San Luis Potosi, are reported to have started operations, and others will do so soon if conditions continue reasonably quiet in Mexico.

The annual progress and developments in the lead-mining industry are shown in the mine reports for the several producing States published in Mineral Resources of the United States. Detailed reports on the ore deposits of many lead-producing districts have also been published by the United States Geological Survey.

EXPORTS.

Large quantities of refined lead produced in the United States from foreign ores or bullion have annually been exported from bonded smelters, but there have been no exports of domestic lead until the recent diminution of imports of lead ore and bullion from Mexico made it necessary to supplement the exports of foreign lead with exports of domestic lead. These began in March, 1914, and have grown larger each year since, more than making up the deficiency of lead of foreign origin.

The increase in the total value of lead exports has been due largely to the increased value of the pig lead exported.

Refined lead produced in the United States and lead exported, 1911–1917.

	Production.		Exports				
			Pigs and bars.				
	From domestic ores (short tons).	From foreign ores (short tons).	Domestic (short tons).	Foreign (short tons).	Lead used in articles exported with benefit of drawback (short tons).	Total value of lead exports.	Value of lead manufactures, domestic and foreign.
1911	391,995	94,984		113,307			
1912	392,517	88,377		76,226			
1913	411,878	50,582		54,301			
1914:							
January-June	512,794	29,328	20,162	8,834	3,798	$3,071,835	$1,266,725
July-December			38,560	12,711	5,640	4,720,112	1,298,306
1915:							
January-June	507,026	43,029	57,952	17,218	3,020	6,973,877	732,906
July-December			30,354	21,400	963	6,357,348	1,578,103
1916:							
January-June	552,228	18,906	46,617	4,744	4,745	8,379,457	1,116,567
July-December			53,883	5,136	426	9,438,261	1,392,252
1917:							
January-March			14,970	1,733	(a)	[b]2,941,954	542,197

[a] Statistics not yet available.
[b] Does not include value of lead used in articles exported with benefit of drawback.

MAGNESITE.

By Hoyt S. Gale.

The production of magnesite in the United States in 1916 far exceeded that of any preceding year. The increase was due to the larger demand for refractory magnesite products and to the decline in imports. Though more magnesite was used in the United States in 1916 than in 1915, the consumption was less than that of any of the three years preceding 1915, and the use of the mineral has now been greatly curtailed by its relative scarcity and high cost.

It is estimated that normally about 6 pounds of magnesite was formerly used for every ton of steel made by the basic open-hearth process, but not more than half a pound for every ton is now being used, and at some steel plants cheaper and less satisfactory refractories have been substituted for magnesite. Owing to its use in the steel and copper industries magnesite is an important though a minor war commodity, and the need for it in these industries is so great that its lack has at times been viewed with serious apprehension.

Magnesite produced in and imported into the United States, 1912-1916, in short tons.

Year.	Domestic production, raw.	Imports "for consumption."		Total consumption calculated as calcined.
		Raw.	Calcined.	
1912	10,512	17,905	125,252	139,460
1913	9,632	13,240	167,094	178,530
1914	11,293	13,354	121,817	134,140
1915	30,499	49,765	26,574	66,706
1916	158,759	75,345	9,270	126,322

The properties that made the largest production in 1916 are in Tulare County, Cal., though considerable quantities were produced also in Santa Clara, Sonoma, Napa, Kern, and Fresno counties, Cal., and from deposits recently opened in Stevens County, in eastern Washington.

The data given above show that 1914 was the last year in which the imports were approximately normal. About 90 per cent of these imports were received from Austria and Hungary, and almost all the rest came directly or indirectly from Greece. The European war at first cut off the shipments from the Austrian and Hungarian deposits, so that for a time the imports of the purer Grecian magnesite greatly increased. Later the lack of boats and the dangers of navigation cut off a large part of the Grecian supplies and stimulated the development of the domestic deposits. In 1915 only 11,000 tons of Austrian magnesite was imported, but the shortage of the supply from Austria was in part replaced by Grecian material and by 2,500 tons of calcined magnesite obtained from Canada. In 1916 the larger part of the imported calcined magnesite came from Greece, although about 2,000 tons was received from Canada. Most of the imported magnesite has come through the port of Philadelphia, but some has come by way of New York and New Orleans.

The most important development of the year 1916 is the opening in eastern Washington of large deposits of a coarsely crystalline magnesite that is like marble or dolomite in texture but is essentially magnesite in composition. This material is now being shipped at the rate of several hundred tons a day, and calcining furnaces are in course of erection to prepare magnesia for use in making refractory material and, it is said, also for use in cement mixtures. Coming at a time when the sources of supplies abroad are cut off, the discovery of these deposits appears to be most fortunate. Apparently authentic reports indicate that the deposits are large and that they will afford a supply of uniform character by relatively cheap methods of mining. It is perhaps too soon to say just how well the material is suited for refractory or other uses, but the present indications are that it may be adapted to some of these uses.

The other large deposits in this country are in California, and the material is of the purer type, like the Grecian, which has ordinarily not been favored for use in furnaces. The cost of mining and of transportation from the Western States to the East, where most of the refractory materials are handled and used, is greater than the cost of mining and of shipping by water from abroad, and this has been the principal fact prohibiting the production of domestic magnesite other than the small quantity used on the west coast, chiefly in the manufacture of paper. Now the higher price offered for magnesite has induced the development of many properties that have hitherto been little worked.

The prices paid in California for the raw ore at the mine or shipping point ranged from $8 to $10 a ton, but though much was shipped raw, a part of the product was calcined at the mine. The eastern users had to pay, in addition to the original price, the relatively heavy charges for transportation, amounting to about $10 a ton. Thus raw magnesite cost the eastern users not less than $18 to $20 a ton, and the added expense of calcining and the resulting loss of weight made the minimum cost, even to large users, very much higher than formerly. However, even at these high prices the demand for magnesite is very great.

Most of the refractory magnesite that has been in general use has peculiar and distinctive properties that are not found in the magnesite deposits of the common type. The value of this refractory material depends not only on its resistance to the corrosive action of heat and metallic slags, but also on the permanence of the forms in which it is put into the furnace. This permanence is due to a natural bonding which tends to make the loose crushed material cling together under furnace heat and thus makes brick forms molded from it more durable. Bricks and granular furnace bottoms made of magnesite that lacks this bond break, and the magnesite floats off on the fluid molten metal and is lost in the slag. Thus, though magnesite that contains a small percentage of iron may be somewhat less resistant to extreme heat than a purer form, the slight fusibility given to the material by the iron tends to hold it in place. For this reason, in part, a type of magnesite so far found only in Austria and Hungary has been the principal source of the refractory magnesia used in this country. The purer magnesite from Greece, California, and elsewhere is used in making plaster or cement or material for other relatively minor uses.

Magnesite is reduced to magnesia either in "dead-burned" or sintered form, or in what is known as "caustic calcined" form, Dead-burned or sintered magnesite has been so strongly heated that essentially all its carbon dioxide and moisture have been driven off and most of the shrinkage taken up. In this condition it is chemically very inert—that is, it is not subject to attack or disintegration even under extreme heat. The caustic form is not so thoroughly calcined; it still retains 1 or 2 per cent of carbon dioxide and is thus a product more like ordinary caustic lime in its properties. although not quite so active chemically. Caustic magnesite "slacks" when exposed to the air, recombining with moisture and carbon dioxide. Combined with calcium chloride it forms a distinctive cement known as Sorel or oxychloride cement, which is much favored by builders for floors and other places where tile or special finish is desired. This is probably the most important use to which pure caustic calcined magnesite is put, although it is used also for making liquors in which wood pulp is digested to make paper, as well as for other purposes.

It is difficult to determine just how much magnesite was formerly used in laying cement flooring, in making paper, and for other purposes. The magnesite-cement flooring trade in the United States, however, is now very large, though the high price of caustic calcined magnesite and the uncertain quality of the material supplied from some sources have undoubtedly greatly restricted its use in cements.

FLUORSPAR.

By Ernest F. Burchard.

Fluorspar is one of the nonmetallic minerals of moderate intrinsic value the demand for which has increased greatly since the beginning of the European war, on account of its usefulness in the metallurgic, ceramic, and chemical industries, especially in the manufacture of open-hearth steel, enameled ware, and hydrofluoric acid.

CHARACTER AND OCCURRENCE.

Fluorspar, or fluorite, chemically calcium fluoride (CaF_2), consists of calcium and fluorine in the proportions of 51.1 to 48.9. The mineral is only slightly harder than calcite and consequently crushes easily, but it may be distinguished from calcite by its failure to effervesce with dilute hydrochloric acid. It crystallizes in the isometric system and is often found in cubical crystals. In color the spar ranges, according to purity, from a clear, colorless, or slightly bluish glasslike substance through various brilliant shades, and much of it is white and opaque. The mineral is usually very pure, some of the material marketed running 98 to 99 per cent of calcium fluoride. It commonly occurs in veins cutting both sedimentary and igneous rocks.

Fluorspar, associated with other minerals, has a broad distribution geographically and a wide range geologically. The deposits thus far exploited in the United States are, however, confined to Arizona, Colorado, Illinois, Kentucky, New Hampshire, New Mexico, and Tennessee.

The Arizona output has come mainly from the Castle Dome district, Yuma County, but during recent years there has been little production. Fluorspar has been reported also in Cochise, Maricopa, Mohave, Pima, Pinal, and Yavapai counties.

In Colorado fluorspar has been mined in Boulder, Jefferson, and Custer counties, along the Front Range, and in Mineral County at Wagon Wheel Gap, and it occurs in many other counties.

The chief deposits in Illinois and Kentucky occur in adjoining portions of the two States, Hardin and Pope counties in Illinois being separated from the Kentucky counties, Crittenden, Livingston, and Caldwell, by Ohio River. The great size and the purity of the fluorspar deposits of the Illinois-Kentucky district indicate that for many years they will continue the main source of domestic production. Prospecting with favorable results has been reported from Mercer County, in central Kentucky. Other Kentucky counties in which fluorspar is reported are Fayette, Jessamine, Trigg, and Woodford.

The deposit thus far developed in New Hampshire is near Westmoreland, Cheshire County.

In New Mexico fluorspar has been mined from several veins 10 miles northeast of Deming, Luna County, and in the Burro Mountain district, Grant County, and is reported also in Bernalillo, Sandoval, and Socorro counties.

The Tennessee production has come from Smith, Trousdale, and Wilson counties, and fluorspar is reported to occur in Carter County.

A possible addition to the list of producing States is California, as fluorspar has been reported in Inyo, Los Angeles, Mono, San Bernardino, and San Diego counties.

Fluorspar is reported to have been separated in the concentration of lead and zinc ores in Albemarle County, Va.; of gold tellurides at Cripple Creek, Colo., and at a number of localities in other States in quantities too small for use at present. Practically, wherever it has been mined, fluorspar occurs as a vein material, although under widely different conditions. In the Kentucky-Illinois district it is the chief mineral of value in the veins, lead and zinc being of secondary importance and, in many places, not valuable even as by-products, but in the Castle Dome district of Arizona jig concentrates of fluorspar have been made incidentally to concentrating the lead-silver ores. Some lump spar has also been saved in this district. In 1916 a small tonnage of spar was reported to have been mined, but not shipped, in Ferry County, Wash.

In England fluorspar occurs abundantly in the Carboniferous limestone and associated shale, limestone, and sandstone of the Yoredale group, where it is found as the gangue of metalliferous veins. It is usually but not invariably associated with calcite, quartz, and barytes. The principal producing localities are in Durham and Derbyshire. A large proportion of the fluorspar produced in England has been obtained by screening from waste dumps of old lead mines, but it is reported that these sources of supply are approaching exhaustion.[1]

In Canada there are deposits of fluorspar, but little has been published concerning them. A small production has been reported from time to time.

---

[1] Strahan, A., Great Britain Geol. Survey Mem., vol. 4, p. ii, 1916.

PREPARATION AND USES.

The uses of fluorspar depend on its chemical composition, fluxing properties, and phosphorescence when heated and on its optical and gemlike properties. Its preparation involves separation from other minerals with which it is associated, the treatment including such processes as hand-sorting, crushing, washing, screening, jigging, and flotation, depending on the nature of the ore and the extent to which concentration is practicable.[1] Part of the high-grade ore is ground and shipped in barrels and sacks; the rest is sold in lump form. Where fluorspar is associated with sphalerite, or zinc blende, complete separation of the two minerals has been difficult on account of their nearness in specific gravity. Although fluorspar is useful in smelting iron ores it is harmful to zinc, and the sulphur in the sphalerite can not be permitted in the iron and steel furnaces, therefore zinc-fluorspar concentrates are of little value unless the fluorite and sphalerite can be cleanly separated. A process for separating these minerals by means of flotation in a dilute solution of aluminum sulphate has been developed, it is reported, at Marion, Ky., the flotation being performed in shallow pans, in which mechanical stirrers are operated.

The three principal industries in which fluorspar is utilized are, in order of importance, (1) metallurgic work, (2) the manufacture of opalescent glass and sanitary and enameled ware, and (3) chemical manufacture. The highest grade, "American lump No. 1," which runs less than 1 per cent silica and is white or clear pale blue or green, is sold either ground or in lumps for use in the glass, enameling, and chemical industries, including the manufacture of hydrofluoric acid. Grinding of the pure, clear spar is unnecessary for some purposes, as the lumps readily decrepitate to a powder when heated. The second grade, "American lump No. 2," is used in blast furnaces in the production of ferrosilicon and ferromanganese and in basic open-hearth steel furnaces to give fluidity to the slag without increasing its temperature and to reduce the contents of phosphorus and sulphur. This grade includes colored spar and may run as high as 4 per cent silica, though most of it is sold with a 3 per cent guaranty. The lowest grade, "gravel spar," including all that contains more than 4 per cent silica as well as spar mixed with calcite, is also largely used in basic open-hearth steel furnaces, where it is added to fluxing limestone, and in iron and brass foundries, where it is of value in making the metal more fluid, in permitting the use of greater quantities of lower grades and scrap, and because it tends to carry phosphorus, sulphur, and other impurities into the slag. It is estimated that about 80 per cent of the domestic output of fluorspar, mainly in the form of gravel spar,

[1] Burchard, E. F., Fluorspar mining and milling at Rosiclare, Ill.: Eng. and Min. Jour., Dec. 2, 1911, pp. 1088-1090; Iron Trade Rev., Dec. 16, 1911, pp. 1046-1051.

and practically all the imported spar is now consumed as a flux in the basic open-hearth steel furnaces. In the Bessemer process it has been used in the form of artificial fluorides of iron and manganese.

Fluorspar possesses a considerably higher quantitative efficiency as a flux than limestone, especially in smelting refractory ores; but in all metallurgic operations the proportions of the spar that can be used are limited, as its favorable effects do not increase indefinitely as the quantity is increased. In England and on the Continent the metallurgic use of fluorspar has heretofore been more common than in America, probably because its value has been better understood by European metallurgists. Other minor metallurgic uses of fluorspar are in the extraction of aluminum from bauxite, in smelting gold, silver, and copper ores, in refining copper, in the electrolytic refining of antimony and lead, and in refining lead bullion. In the last-named process the spar is first converted into hydrofluoric acid. In the extraction of aluminum fluorspar is reported to be fused with bauxite and soda ash into a product resembling an artificial cryolite (sodium-aluminum fluoride), to which more bauxite is added, and from this mixture aluminum is extracted in the electric furnace. Miscellaneous uses that have been reported are as a bond for constituents of emery wheels, for carbon electrodes to increase their lighting efficiency while also decreasing the amount of current required, in the extraction of potash from feldspar, and in the manufacture of Portland cement.

Fluorspar for iron and steel making should carry at least 85 per cent calcium fluoride and preferably more, and it should be free from sulphides and sulphates. For most other chemical uses it should contain 95 to 98 per cent or more of calcium fluoride.

The following analyses of gravel fluorspar, most of them made in laboratories of steel works, show the character of commercial shipments of spar. The spar from Colorado and New Mexico has not been washed; that from Illinois and Kentucky has been subjected to mechanical treatment, including washing.

Analyses of gravel fluorspar from Colorado, New Mexico, Illinois, and Kentucky.

Locality.	Calcium fluoride (CaF_2).	Silica (SiO_2).	Oxides, mostly iron (Fe_2O_3) and alumina (Al_2O_3).	Calcium carbonate ($CaCO_3$).	Barium sulphate ($BaSO_4$).
Colorado:					
Jamestown	82.16	10.64	4.27	2.26	....
Jefferson	68.34	28.33	1.69	1.34	....
Morrison	72.21	21.93	3.08	2.78	....
Rosita	86.75	9.3	4.2	....	....
Wagon Wheel Gap	90.08	2.21	2.14	1.17	3.22-6.00
New Mexico:					
Near Deming	92.31	5.28	1.07	1.19	....
Do	88.94	8.35	1.20	1.34	....
Illinois:					
Rosiclare	87.64	4.15	1.58	6.41	....
Do	90.41	3.35	1.03	4.33	....
Fairview	88.85	3.4	1.45	....	....
Do	87.07	3.12	....	8.96	....
Kentucky:					
Marion	87.8	3.10	2.06	....	....
Do	90.02	4.72	1.5	....	....

The following notes[1] on the use and requirements of fluorspar for optical purposes have been published by the Kentucky Geological Survey:

An apochromatic lens is one that shows objects viewed or magnified through it more nearly free from color rings than is obtainable with any other kind of lens. For this purpose certain transparent minerals crystallizing in the isometric system (cubes, octahedrons, etc.) come nearest fulfilling the required conditions, because they do not show objects viewed through them double (double refractions). The diamond is suitable when found completely transparent, but owing to its high refractive power and reflection from two faces rarely occurs in this condition, not to mention its prohibitive high cost and difficulty of grinding.

Fluorspar has low refractive and dispersive powers and hence is especially adapted to the production of such lenses, as was pointed out by Abbe. It is much sought after by European optical makers where perfect lenses are necessary for the highest class of such instruments as spectroscopes, etc. Such lenses show very low differences because of refraction. For the three hydrogen lines H_α, H_β, and H_γ the differences in refractive indices are $n_\beta - n_\alpha = 0.00455$ and $n_\gamma - n_\beta = 0.00255$. (Dana, New system of mineralogy, 1901, p. 1034.) It is of special value for certain work in ultraviolet light.

Fluorite pellucid (water-clear) enough for this purpose is, however, extremely rare. It is to be found in simple crystals of fluorspar groups which are either colorless or very light yellow, green, blue, etc. As the crystal faces are usually dull or have a satin luster, it is necessary to cut off (truncate) the corners of the cubes along cleavage planes, to determine whether it contains any sufficiently clear and flawless. The clearest portion usually occurs in the center of the triangular face exposed by truncation. A peculiar property of fluorite of this quality is its conchoidal (irregularly curved) fractures and less facile cleavage. Twinned crystals usually show flaws due to striae along twinning planes, hence do not contain optical fluorite. Pieces as small as one-quarter inch across may serve for lenses, though, of course, larger ones are more valuable. Prices range according to size and quality of pieces.

As indicated above, fluorspar suitable for optical purposes is very rare and difficult to obtain. At present there is no reported domestic production of it. Some absolutely clear fluorspar has been imported from Japan and has been valued at about $30 an ounce. Such fluorspar has been used as part of the lens in a telescope in order to correct certain color effects, and pieces only a few millimeters thick will suffice.

There is an abundance of crystalline fluorspar in southern Illinois, western Kentucky, southwestern New Hampshire, and at many places in Colorado, New Mexico, and Arizona, but most of the material is colored faint to deep shades of purple or green. In the hope of finding a domestic supply of fluorspar suitable for optical purposes the United States Geological Survey has already communicated with the fluorspar producers of the country, earnestly requesting them to watch carefully for any crystals that may appear exceptionally clear and free from flaws or fractures, and to notify the Survey if anything is discovered that may be thought to be of value for the purposes mentioned in order that arrangements may be made for testing the material. In response to the letters of the Survey several promising samples had been received from domestic sources up to July 15, 1917.

[1] Fohs, F. J., Fluorspar deposits of Kentucky: Kentucky Geol. Survey Bull. 9, pp. 178–179, 1907.

INDUSTRY PRECEDING AND DURING THE WAR.

Prior to 1905 the production of fluorspar was less than 50,000 short tons annually; up to 1908 it fluctuated considerably, but in 1909 it began to increase rapidly, owing to the more general recognition of the value of fluorspar in the manufacture of open-hearth steel and to the expansions in facilities for mining and milling the mineral in Illinois and Kentucky. There was a steady increase in production from 1908 to 1912, but in 1913 and 1914 there were decreases coincident with depression in the steel industry. In 1915 and 1916 the production largely increased, owing to the revival of the steel and chemical industries, the output for both of these years exceeding all previous records. During the period 1910 to 1916, for which complete records are available, there has been almost steady decrease in imports, but the considerable falling off during the war years may be attributed to the interruption to commerce as well as to depression in the mining industry in England caused by the scarcity of available miners.

Fluorspar produced and imported before and during the war, in short tons.

Year.	Production.	Imports.
1911	87,048	32,764
1912	116,545	26,176
1913	115,580	22,682
1914	95,116	10,205
1915	136,941	7,167
1916	155,735	12,323

From this table it is apparent that American fluorspar deposits have proved ample to supply more than the additional fluorspar needed to make up for the decrease in imports. There are no considerable exports of fluorspar at present, so that the consumption is represented practically by the domestic production plus the imports. This is shown graphically in figure 5.

The average price of domestic fluorspar at mines or local shipping points, for all localities and all grades of spar, has ranged between $5.50 and $6.50 a short ton during the last four years. The price decreased from 1913 to 1915 but increased more than 50 cents a ton in 1916. Ground spar has commanded the highest price—from $10.75 to $13.15 in recent years; lump spar has brought from $6.90 to $13, and gravel spar from $4.85 to $10 a ton, the price depending on quality, locality, and condition of the market.

Practically all the fluorspar imported in recent years has been a medium-grade gravel spar, brought over either as ballast or at a very low ocean freight rate, and, having been recovered from old mine dumps, it can be sold at a low figure on the American market. The highest average valuation assigned to such spar in the last six years is $4.38 a ton in 1916, and the lowest is $2.46 in 1911. These values do not include the duty, which, together with freight charges, must be added to the declared value in order to arrive at an average approximation of cost to the consumer. A tariff of $3 a ton was imposed on imported fluorspar by the Payne-Aldrich bill in August, 1909. Prior to that time the mineral had been imported duty free.

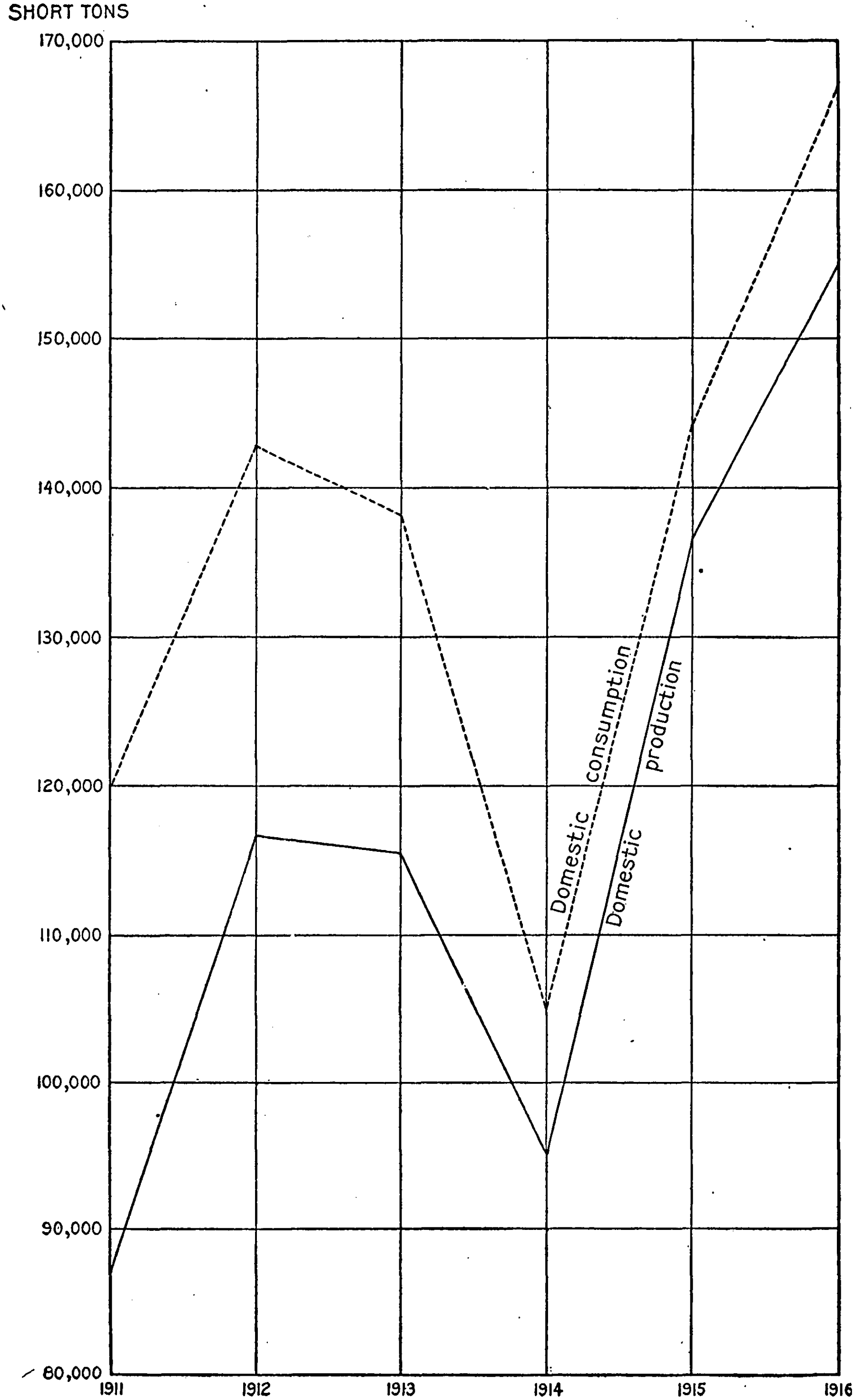


FIGURE 5.—Domestic production and consumption of fluorspar, 1911-1916.

The Underwood bill reduced the duty to $1.50 a ton in October, 1913. Gravel spar from England has always competed with the domestic product at the steel furnaces on or near the Atlantic seaboard and at times as far west as Pittsburgh and has practically fixed the price in that territory, but since imports have been curtailed the domestic product has been in greater demand and has sold at better prices in the eastern market.

SUPPLIES.

No attempt has ever been made to estimate the fluorspar reserves in the United States. Field work by the United States Geological Survey and the Kentucky Geological Survey has shown conclusively, however, that the deposits in Illinois and Kentucky are of sufficient extent to supply for many years demands much greater than at present. Reconnaissance by the Federal Survey indicates that Colorado, New Mexico, and New Hampshire possess deposits that may be drawn upon to supplement the supply from the larger deposits for a considerable period. Moreover, the deposits reported to have been discovered in numerous other States promise to yield commercial quantities of spar from time to time as transportation facilities are developed. The geologic relations of the known deposits indicate that many more of similar grade and extent should be discovered as prospecting progresses in mining regions in the Central and Western States. If the demand should ever greatly exceed the supply from the present principal domestic sources a considerable quantity might be obtained by saving the concentrates at metalliferous mines, although this would involve in most places the separation of fluorspar from other gangue minerals, and the price would have to be much higher than at present to render this procedure profitable.

It is probable that little dependence can be placed on a steady supply of fluorspar from England during war years. In normal years more than 50 per cent of the English production has been shipped to the United States. Probably this was a surplus, but it is doubtful whether in the next five years there will be any such surplus available, as the demands in Great Britain are certain to be heavier than before the war. Furthermore the foreign spar is of lower grade than the mechanically treated spar from Illinois and Kentucky and the high-grade vein material of New Hampshire, Colorado, and New Mexico, and as fluorspar is of value chiefly according to its purity, purchasers find that the American product is more efficient and consequently cheaper in the end. At any rate, there should be no necessity for the United States to experience a shortage of fluorspar except through lack of miners, labor troubles, or scarcity of boats and cars to move the product. The largest mines are partly dependent on Ohio River for transportation of fluorspar to railroad shipping points.

PETROLEUM.

By John D. Northrop.

INTRODUCTION.

Among the mineral substances that contribute to the successful conduct of modern warfare petroleum occupies a position of great importance. In its crude or semirefined state petroleum is the most efficient and economical fuel available for the propulsion of battleships, torpedo boats, transports, and merchant vessels and has been adopted for this purpose by the great navies of the world. Behind the first line of defense oil is the principal fuel of many large industrial plants and of many railroads of strategic importance whose lines traverse sections of the country that are devoid of other fuel resources.

Of even greater industrial importance than petroleum itself are the products derived from it. Gasoline is the principal fuel of internal-combustion engines and as such is an essential requirement ior the operation of automobiles, motorcycles, autotrucks, airplanes, armored cars, and motor boats. Mineral lubricants are required wherever machinery is operated. Kerosene is utilized as a fuel in the camp kitchen and as a source of light where other illuminants are not available. Engine distillate is a necessary fuel for engines of the Diesel and semi-Diesel type utilized on undersea and surface craft. Paraffin wax is becoming increasingly important as a surgical dressing, and in the realm of therapeutics the places of cymogene, rhigolene, and petrolatum, both solid and liquid, have long been fixed.

Even a casual review of these principal applications of petroleum in modern warfare is sufficient to indicate the vital necessity to a warring nation of an abundant supply.

POSITION OF THE UNITED STATES IN THE PETROLEUM INDUSTRY.

The position of the United States with respect to petroleum resources is most enviable. Its annual output constitutes two-thirds of the world's current supply and in 1916 amounted to 300,767,158 barrels of 42 gallons each. From 1859, when the petroleum industry began in the United States, to the end of 1916 this country produced approximately 4,000,000,000 barrels of crude oil, or more than 60 per cent of the total quantity produced in the entire world in this period. The accompanying diagram (fig. 6) shows graphically the

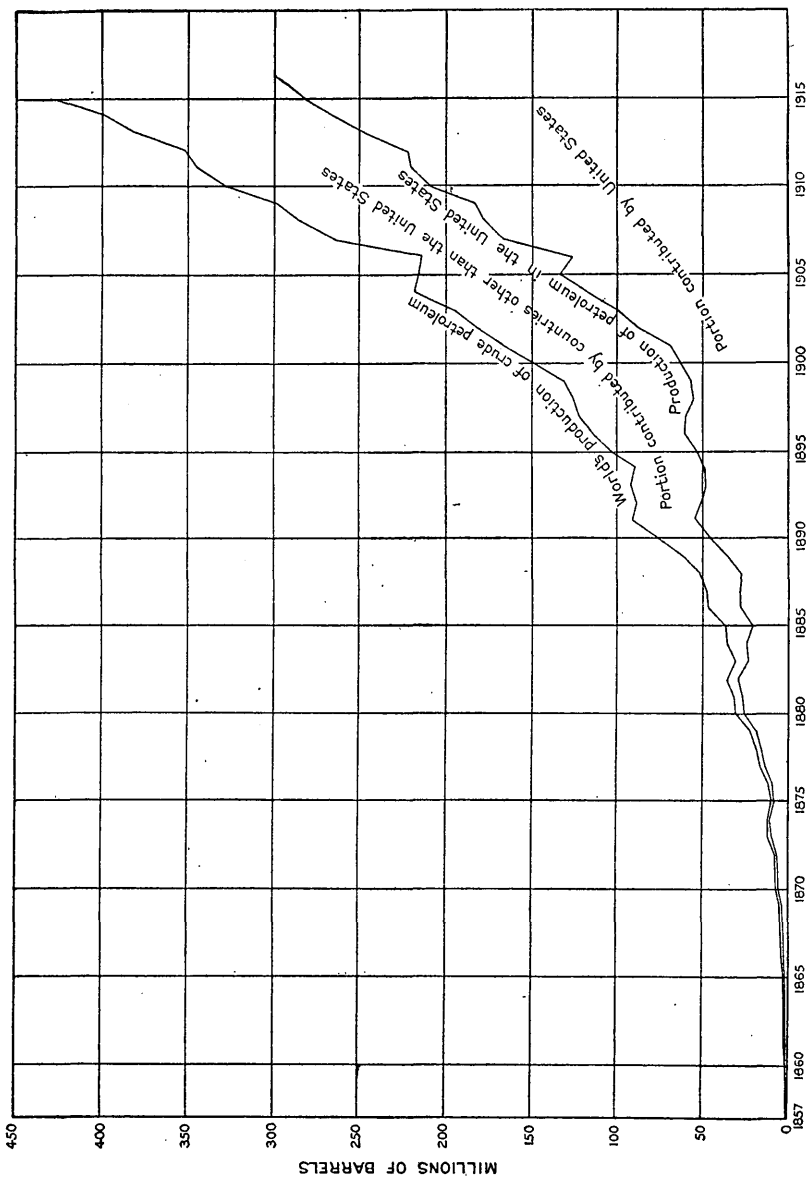


FIGURE 6.—Graph showing the total quantity of petroleum marketed annually in the United States from 1859 to 1916 and the total quantity produced annually in all other countries of the world from 1857 to 1916.

annual output of crude petroleum in the United States since 1859 and the relative importance of the United States as a contributor to the world's supply of this mineral.

SOURCES OF DOMESTIC SUPPLY.

Crude petroleum is produced in commercial quantities in 18 States and in the Territory of Alaska and is reported to have been discovered recently in the Department of Mindanao, P. I. The relative importance of these sources as contributors to the petroleum supply of this country is shown in the following table, which includes statistics for 1916 and cumulative totals of the quantity produced since the beginning of the petroleum industry in each State:

Crude petroleum marketed in the United States in 1915 and since 1859.

[In barrels of 42 gallons each.]

State.	1916	1859-1916
Alaska, Michigan, Missouri, and New Mexico	7,705	94,682
California	90,951,936	918,817,030
Colorado	197,235	11,054,853
Illinois	17,714,235	269,082,546
Indiana	769,036	104,468,594
Kansas	8,738,077	40,108,638
Kentucky and Tennessee	1,203,246	10,736,490
Louisiana	15,248,138	123,335,110
New York	874,087	(a)
Ohio	7,744,511	448,331,841
Oklahoma	107,071,715	666,820,434
Pennsylvania	7,592,394	a 771,373,177
Texas	27,644,605	256,386,687
West Virginia	8,731,184	278,228,797
Wyoming and Montana	6,279,054	18,489,523
	300,767,158	3,917,328,402

a New York included in Pennsylvania.

The areas in which crude petroleum is produced in the United States are assigned to ten major fields. This division, though mainly geographic, incidentally expresses to a considerable degree differences in the characteristics of the oil produced.

1. The Appalachian field includes all areas of oil production in southwestern New York, western Pennsylvania, eastern Ohio, West Virginia, Kentucky, and Tennessee. The crude oils produced in this field range in gravity from 25° to 50° Baumé, are in the main of paraffin base, are free from asphalt and objectionable sulphur, and yield by ordinary refining methods relatively high percentages of gasoline and illuminating oils. Near Franklin, Pa., Volcano, W. Va., and Mecca, Ohio, small quantities of high-grade petroleum suitable in the crude state for lubrication are produced. The Appalachian field has been under development for more than 50 years, and though its annual production is still in excess of 20,000,000 barrels, its output of petroleum is declining steadily at an average rate of 5 per cent a year. Its productive areas are practically all developed with the exception of the south end, where considerable undeveloped territory of promise has in the last year been proved to exist in Kentucky and Tennessee.

2. The Lima-Indiana field embraces the areas of petroleum production in western Ohio and in Indiana. The product of this field ranges in gravity from 30° to 35° Baumé and is of paraffin base, though containing a small proportion of asphalt. Objectionable sulphur compounds that require special refinery treatment for their removal are also present. This field has been under development since 1885. Its annual production has declined steadily since 1904 and in 1916 was less than 4,000,000 barrels. Well-directed effort over a period of many years has failed to disclose any evidence that the productive area of this field can be materially increased, though its present limits are acknowledged to include considerable territory that is not completely drilled. In such territory operations have been retarded by a scarcity of cheap fuel. In western Indiana the discovery and development of small isolated pools of oil is expected to extend the date of ultimate exhaustion of the Lima-Indiana field many years into the future.

3. The Illinois field includes the principal area of oil production in the southeastern part of Illinois, as well as a number of scattered pools of small individual extent in the central and western parts of the State. The oil in this field ranges in gravity from 28° to 40° Baumé and contains varying proportions of both asphalt and paraffin. Sulphur is generally present but rarely in such form as to necessitate special treatment for its removal. Illinois has been an important contributor to the petroleum supply of the United States since 1906, its output in 1908 reaching a maximum of nearly 34,000,000 barrels. Since 1908 its production has declined at a moderate rate, and in 1916 it amounted to only 17,714,235 barrels. Aside from minor pools that may be discovered from time to time in the western part of the State,. the productive oil territory in this field is believed to be now under development. A steady though gradual decline in production of petroleum is predicted for the Illinois field.

4. The Mid-Continent field includes all areas in which petroleum is produced in Kansas and Oklahoma. The field has been a large contributor to the petroleum supply of the United States since 1904, and in the last two years it has furnished more than 35 per cent of the petroleum produced in the entire country. The oils of this field vary in composition within wide limits, ranging from asphaltic varieties that are lean in gasoline and illuminants to high-grade paraffin oils that yield a large percentage of the lighter products of distillation. The range in gravity is between 27° and 42° Baumé. Sulphur is present in varying quantities in the lower-grade oils, in certain of which—the Healdton grade, for example—it exists in a form that necessitates special treatment for its elimination. Although this field is believed to have attained its maximum annual production, amounting to 115,809,792 barrels, in 1916, it is destined to remain

the principal contributor to the petroleum supply of the country for many years, as its productive districts are only partly drilled, and its boundaries embrace large areas of untested and apparently not unfavorable territory.

5. The north Texas field includes a number of detached areas of oil production in the northern and east-central parts of Texas. The oils produced are in general similar to those of the Mid-Continent field, with the exception of that obtained in the Powell pool, Navarro County, which has a gravity of about 23° Baumé and is of little commercial value except as a fuel. Aside from the Navarro County district, including the Corsicana and Powell pools, which have produced petroleum since the early nineties, the north Texas field has been an important source of oil only since the development of the Wichita district, including the Electra and Burkburnett pools, in 1912. Since that year its yield has been in excess of 9,000,000 barrels annually. Considerable undrilled territory of promise is included in this field, the development of which should serve to maintain production at the present rate for two or three years at least.

6. The north Louisiana field includes the areas of petroleum production in Caddo, De Soto, Bossier, Red River, and Sabine parishes. The oils of this field range in gravity from 22° to 42° Baumé and are of paraffin base, though containing ordinarily small percentages of asphalt. Sulphur is present in the oils of lower gravity. The north Louisiana field became important as a source of petroleum in 1910 and attained its record production of 15,082,034 barrels in 1915. Individual wells and pools in this field are not long lived, and although the productive area of the field has not been completely drilled and its boundaries have not been fully determined, there is little basis for believing that new territory will be developed in the future with sufficient rapidity to more than offset the decline in preduction of the old wells or to increase the output of the entire area beyond 12,000,000 barrels a year.

7. The Gulf field includes a large number of detached oil pools associated with saline domes in southeastern Texas and southern Louisiana. Oils from the Gulf field, though variable in composition, are characterized by relatively high percentages of asphalt and low percentages of the lighter distillation products. In general they range in gravity between 15° and 28° Baumé and contain considerable sulphur, much of which is in the form of sulphureted hydrogen and is easily removed by steam before the oil is utilized.

The low-gravity oils from this field are used chiefly as fuel and for the manufacture of asphalt and asphalt products. The lighter grades are refined and yield lubricating oils of superior quality. The production of individual pools in this field has been remarkably large, but once the maximum yield is attained the output declines abruptly to a relatively low rate, which is, however, maintained for many years. Owing to the number of individual pools involved and to the peculiar mode of occurrence of the oil, the production in the Gulf field is extremely erratic. Between 1901 and 1905 the output increased from 3,500,000 to 36,500,000 barrels. In 1906 it was 20,500,000 barrels; subsequent to that year it declined to as low as 8,500,000 barrels in 1912 and 1913 but increased with the discovery of deep sands in the Humble pool, Harris County, to about 20,500,000 barrels in 1915 and 1916. The future of the Gulf field is conjectural. The developed pools represent but a fraction of the vast area of the Gulf Coastal Plain, much of which has not been adequately tested by the drill. Recent discoveries of petroleum in commercial quantities at Damon Mound, Brazoria County, Tex., at Big Hill, Matagorda County, Tex., and near Houma, New Iberia Parish, La., indicate that the petroleum output of the Gulf field will probably be maintained at the present rate for at least two years more, and that the probabilities of the discovery of additional pools of oil in this area are high. Whether the new pools will be of sufficient capacity or will be discovered rapidly enough to sustain or increase the present rate of production of the field as a whole is purely a matter of speculation.

8. The Rocky Mountain field includes all areas of petroleum production in Colorado, Wyoming, and Montana, as well as areas of prospective oil production in Utah and New Mexico. Crude oils from this field are in the main of paraffin base and yield relatively high percentages of gasoline, illuminating oils, lubricants, and fuel distillates. The greater part of the oil produced ranges in gravity from 32° to 48° Baumé and contains little or no objectionable sulphur. Heavy asphaltic oils, ranging in gravity from 18° to 24° Baumé, suitable chiefly for fuel or for the manufacture of asphalt, are obtained in certain parts of this field. As a contributor to the petroleum supply of the United States the Rocky Mountain field is in its infancy, its production prior to 1912 averaging considerably less than 1,000,000 barrels a year. Since 1912 its production has increased rapidly, amounting to about 6,500,000 barrels in 1916 as a consequence of active operations in Wyoming and southern Montana.

In addition to large areas of prospectively favorable but as yet untested oil territory, the Rocky Mountain field includes a vast acreage of easily accessible oil shale that averages in petroleum content between 15 and 60 gallons to the ton. It is estimated that in northwestern Colorado alone there are 39 townships (1,400 square miles) underlain by an average thickness of 53 feet of shale in beds 3 feet or more in thickness, which, according to field tests, will yield on distillation an average of 25 gallons of crude oil to the ton of rock. Crude oil from these shale beds will yield by ordinary refining methods approximately 9.5 per cent of gasoline, and by modern cracking processes a much larger proportion. An equivalent or larger area of equally rich oil shale exists in northeastern Utah and southwestern Wyoming.

The net result of field investigations conducted by the United States Geological Survey is that these shale areas constitute a latent reserve of crude petroleum, the possible yield of which is much in excess of the past and future supply of petroleum obtained and obtainable from wells in the United States. The development of this vast reserve of crude petroleum must be undertaken in the near future if the growing demand for petroleum products in the United States and elsewhere is to be supplied. The construction of a pipe line from western Colorado to connect with the trunk lines in Kansas for the purpose of conveying shale oil to the refineries of the Mid-Continent and Atlantic seaboards may easily mark the dawn of the next great epoch in the petroleum industry of this country.

The development of the petroleum industry in the Rocky Mountain field has been retarded by a lack of refining and transportation facilities. This lack is now being rapidly supplied, and production is steadily increasing. The area of prospective oil territory in Wyoming particularly is large, and proved districts are numerous and by no means completely drilled.

9. The California field embraces all areas of oil production in that State. The oils of this field are in the main of asphalt base and range in gravity from 12° to 35° Baumé. Relatively small quantities of paraffin-base oils are found in certain localities. About 25 per cent of the petroleum produced in California is used for fuel or for the manufacture of asphalt and asphalt products. The remainder is subjected to some form of refinery treatment, its chief products being fuel oils, lamp oils, lubricants, road oils, and paving materials. The lighter-gravity oils yield a fair percentage of gasoline and naphtha. As indicated in the table on page 3, California has yielded more oil than any other State. Its maximum annual production is believed to have been reached in 1914, when the output was about 100,000,000 barrels. Its productive areas are considered to have been essentially outlined and their periods of flush yield to have been passed. Considerable undrilled acreage remains, however, within the areas outlined, the development of which, if not interrupted, would doubtless serve to maintain a relatively high rate of production for the next two or three years, after which an appreciable decrease appears certain.

10. The Alaska field is at present unimportant as a contributor to the petroleum supply of the country. As now developed it consists of a few producing wells near Katalla that yield a high-grade

paraffin-base oil ranging in gravity between 39° and 45.9° Baumé. Further drilling is necessary to determine the presence or absence of a valuable pool of oil in this district. Seepages of petroleum are known elsewhere in Alaska, as near Yakataga and adjacent to Iniskin Bay and Cold Bay, but their value as indicators of notable accumulations of petroleum is as yet undemonstrated.

INFLUENCE OF THE EUROPEAN WAR.

Coming at the climax of a period of gross overproduction of crude petroleum in the United States, the unexpected outbreak of the European war in 1914 resulted in a demoralization of export facilities that reacted adversely on the entire petroleum industry of the country. The increased hazards of ocean traffic forced freight rates to unprecedented heights. A great number of bulk and case carriers of petroleum and its products were either tied up in foreign ports or promptly withdrawn from commercial service, and charters for foreign conveyance were difficult if not impossible to obtain. As a consequence refinery stocks of all petroleum products increased so rapidly that operations at many plants were temporarily suspended. This condition brought about an accumulation of stocks of crude petroleum held by pipe-line companies and by oil producers that reacted unfavorably on an already depressed market for crude oil and resulted in a decided curtailment of drilling activity in all fields.

Owing to the prompt action of the Entente powers in securing mastery of the seas, to the urgent need by the belligerent nations for gasoline, lubricants, and engine distillates, and to a remarkable increase in the demand for motor fuels and lubricants in the United States, the demoralization occasioned by this combination of depressing influences was of short duration. Before the end of 1914 the export situation had improved materially. The shortage in bottoms was rendered less acute by the transfer to American registry of many oil carriers formerly operated under foreign flags, by the conversion of a few bulk carriers to case carriers, and by the employment of sailing vessels of all types for the conveyance of case oils.

Emerging from this period of readjustment the American petroleum industry found the large foreign markets for illuminating oil of which it had been deprived by reason of the blockade declared against the ports of the Central powers replaced by larger and more attractive markets for other and similar products in the Entente and neutral countries. The destruction of the Galician oil fields early in the war, together with the isolation of the Rumanian fields and the cessation of foreign exports from the Russian fields as a result of the closing of the Dardanelles, presented an opportunity for increased export trade in western Europe and elsewhere that American refiners and exporters were not slow to recognize. The steps taken to supply these markets as well as the rapidly expanding home market for petroleum products resulted in a prompt stabilization of conditions throughout the industry. Shipyards were overtaxed with orders, pipe-line capacities were increased, new refineries were installed throughout the Mid-Continent region, and the vast field accumulations of crude petroleum in this area were withdrawn from the open market, passing into the control of a few far-sighted companies that had the courage of their convictions and the capital with which to back them. The withdrawal of this storage oil from the open market resulted in an increased demand for oil produced in other fields and was accompanied by advancing prices for all grades of crude oil. Before the end of 1915 activity in drilling had attained normal proportions in practically all fields and was spreading out from proved areas in quest of new territory.

During the six-month period ending with January, 1915, the foreign trade of the United States in petroleum and its liquid products decreased steadily, the net loss being 10 per cent in gross quantity compared with the six-month period ending with January, 1914, and about 14 per cent compared with the six-month period ending with July, 1914. Subsequent to January, 1915, foreign shipments of petroleum and its liquid products increased notably in quantity, the gross exports in 1915 exceeding those in 1914 by more than 88,000,000 gallons, or nearly 4 per cent. In 1916 the gain over 1915 was nearly 11 per cent.

The following table, compiled from the records of the Bureau of Foreign and Domestic Commerce, shows the trend of the foreign trade of the United States in crude petroleum and its principal liquid products during the last four years:

Mineral oils exported from the United States, 1913–1916, in gallons.

Kind.	1913	1914	1915	1916
Crude petroleum	194,469,634	124,735,553	158,263,069	172,027,903
Gasoline and naphtha	188,043,379	209,692,655	281,609,081	355,870,283
Illuminating oils	1,119,441,243	1,010,449,253	836,958,665	854,688,404
Lubricating oils	207,639,092	191,647,570	239,678,725	260,805,939
Fuels, including gas oils and residuum	426,872,373	703,508,021	812,216,209	964,089,837
	2,136,465,721	2,240,033,652	2,328,725,749	2,607,482,366

The outstanding features of this tabulation are the enormous gain in foreign shipments of gasoline, liquid fuels, and lubricants and the diminished but now recovering demand abroad for illuminating oils and for crude petroleum.

With regard to the importation of crude petroleum and its products by the United States, the influence of the war has been relatively slight. The bulk of the petroleum imported by the United States consists of crude oil from Mexican ports, imported for use as fuel and in the manufacture of asphalt. The normal increase in domestic demand for liquid fuels would readily account for the increase in the quantity of crude oil imported during the last four years, as shown in the following table, compiled from the records of the Bureau of Foreign and Domestic Commerce:

Crude petroleum imported for consumption in the United States, 1913–1916.

[In barrels of 42 gallons each.]

1913	17,809,058
1914	17,247,483
1915	18,140,110
1916	20,570,075

Among the minor products of petroleum imported in considerable quantities for consumption in the United States prior to the war is paraffin oil, principally liquid petrolatum, a carefully refined medicinal oil having about the consistency of light lubricating oil, imported from Russia and utilized as a vehicle for protective sprays in nose and throat treatment but more especially for internal administration as a laxative. The development of the market for oil of this type, on the basis of the Russian product, was largely a matter of convenience rather than necessity, inasmuch as oils of essentially the same characteristics can be refined from certain grades of petroleum available from domestic sources. At the outbreak of the European war direct importations of this material abruptly ceased, though they were resumed to some extent a few months later. Before such resumption, however, American refiners had seized the opportunity presented and had supplied the domestic market with American-made substitutes, with the success indicated in the following table, which shows the steady decrease since 1913 in importations of paraffin oil:

Paraffin oil imported for consumption in the United States, 1913–1916.

[In barrels of 42 gallons each.]

1913	3,676
1914	2,481
1915	1,707
1916	901

The less direct influence of the European war on the petroleum industry of the United States has been manifest in a variety of ways.

The impulse given to practically all industries by increased foreign demand for iron, steel, and agricultural products in particular resulted in general prosperity that reacted in a remarkable expansion in the automobile industry and in the utilization of power machinery on farms throughout the country. As a consequence, the domestic market for gasoline and lubricating oils increased so greatly that petroleum refiners were forced to exert every effort to meet the current demand. This condition brought about the erection of a great number of new refineries, the enlargement of many already established, and a general effort to devise new methods and processes for increasing the percentage of gasoline recovered from crude petroleum.

Thanks to the ability of the oil fields of the United States to respond to increased demands for crude petroleum, to the success of certain of the modern processes for increasing the relative proportion of gasoline that can be manufactured from petroleum (notably the Burton process), and to the development of efficient methods for the extraction of gasoline from natural gas, the domestic and foreign demand for motor fuels has thus far been approximately met.

The curtailment of imports of certain chemicals utilized in petroleum refining has resulted in an appreciable increase in the cost of refinery treatment of crude petroleum since July, 1914. The demand for iron and steel in wartime industries has resulted in a scarcity of structural steel, casing, pipe, and drilling supplies that has not only increased the cost of drilling and of petroleum transportation but has necessitated the repression of field operations and the delay or indefinite postponement of pipe-line and refinery betterments.

INFLUENCE OF THE WORLD WAR.

The entrance of the United States into the European conflict as a belligerent on the side of the Entente powers has given this struggle the status of a world war. The opportunity of supplying our allies with petroleum and its products has now become a duty that the petroleum industry of this country must exert itself to the utmost to fulfill. To the task set before it this industry brings an equipment of oil-transporting and oil-refining facilities adequate to meet normal requirements and capable, if adequately supplied with iron and steel, of rapid expansion to any magnitude that may be justified by the quantity of crude petroleum available. The principal question is whether or not the sources of crude petroleum in the country can meet the demands that must be made on them both at home and abroad. Their capabilities in this regard have already been touched on in the foregoing discussion of individual fields.

On the whole the outlook is not such as to encourage optimism in view of the fact that the present rates of oil production and of oil consumption in the United States are approximately equivalent and that the total reserves of crude petroleum held by pipe-line companies and large refineries were depleted to the extent of nearly 15,000,000 barrels in the last half of 1916. The total surface reserve of crude petroleum in the United States on January 1, 1917, is estimated at 175,000,000 barrels, a quantity none too large to stabilize

127972°—19——13

conditions in an industry that requires 25,000,000 barrels of oil a month for current needs.

If normal demands for petroleum products can barely be met by current production of crude oil, supplemented as to gasoline supply by the contributions of the casing head gasoline industry, the abnormal demands occasioned by the entrance of the United States into the world war render imperative an immediate increase in production. From a review of the fields in which, it appears reasonable to believe, well-directed effort would result in prompt and substantial gains in production, Kentucky, Oklahoma, the Gulf field, Wyoming, and the shale area of western Colorado and eastern Utah stand forth as most promising. To effect the increase that seems possible in these areas, however, and in fact to maintain production at the present rate (July, 1917), it is necessary that the existing famine in pipe, casing, and drilling supplies be remedied at once. Proved areas, no matter how productive of oil, can not be developed without casing, nor can oil be marketed efficiently without pipe lines. This fact can not be too strongly emphasized. The potential yield of the Irvine pool, Estill County, Ky., has been estimated as high as 4,500,000 barrels a year. Petroleum is now being marketed from this pool at the rate of only 1,500,000 barrels a year because of a lack of pipe-line facilities.

Oklahoma is plentifully supplied with refining facilities and with ample pipe-line outlets to the Atlantic and Gulf seaboards and includes within its borders the Osage Indian Reservation, the unleased portion of which constitutes one of the prospectively richest sources of petroleum in the United States. Development in Oklahoma and Kansas is seriously retarded by the acute famine in well casing and other drilling supplies. The same condition prevails in Texas and Louisiana, where considerable territory, both proved and prospective, remains undrilled. In Wyoming field development and oil production are now in excess of transportation and refinery facilities, but this discrepancy is being remedied as rapidly as practicable by the construction of new pipe lines and by the enlargement of existing refineries. Betterments now in progress will result before the end of 1917 in placing the Wyoming and Colorado branches of the petroleum industry in a position to supply a larger proportion of the domestic requirements of petroleum products of the Middle West and Rocky Mountain regions than in the past and thus release for eastern consumption or export more of the output from Mid-Continent and Appalachian sources.

Though representing a vast resource of petroleum, the oil shales of Colorado and Utah can not be considered an emergency source of oil. Methods of mining, crushing, and retorting the shale are yet to be developed. Pipe lines must be constructed to existing refineries or new plants erected near the sources of supply. Unknown difficulties must be overcome before the shale-oil industry can either supplement or supersede the crude-petroleum industry.

In consideration of the steadily increasing demand for petroleum and its products both at home and abroad and of the primary dependence not only of this country but of its allies on the sources of petroleum in the United States for aid in the successful conduct of the war, it is obvious that a serious shortage in the supply of motor fuel is imminent. This famine can be deferred by the exercise of strict economy in the utilization of the supply now available by every operator of a motor vehicle in the country and by the curtailment of the use of gasoline-driven vehicles for pleasure and for such business purposes as can not be efficiently accomplished by the substitution of electrically propelled vehicles. It may be still further deferred by the substitution in a multitude of small plants of one kind or another throughout the country of water, steam, or electric power for that now derived from gasoline.

No commercially practicable substitute for gasoline as a motor fuel has yet been discovered or devised, nor can it be expected that one will be made available in time to assist the United States and its allies in winning the war.

In the light of this fact, the conservation of existing gasoline supplies and the discovery and development of new sources of petroleum stand forth as opportunities for patriotic service that are presented to a surprisingly large proportion of the population of this country and that can not be ignored under penalty of an irreparable loss in the fighting efficiency of this Nation and of the nations with which it is leagued in the greatest conflict the world has ever known.

MANGANIFEROUS IRON ORES.

By E. C. Harder.

INTRODUCTION.

The dependence of the United States on imported high-grade manganese ore and ferromanganese is well known to steel makers and other users of manganese. Normally the high-grade manganese ore produced in this country constitutes less than 2 per cent of the total amount of manganese ore consumed, not including the ore represented by the manganese imported in the form of the alloys ferromanganese and spiegeleisen. During 1916 the domestic production was about three times that of 1915, largely on account of the high prices paid for ore. The exploration for new deposits has also been stimulated, and many discoveries of manganese ore are being reported. Even with this outlook for increased production, however, it is not unduly pessimistic to say that the deposits of high-grade manganese ore in the United States will probably never be able to supply the manganese consumed in domestic industries. If, therefore, the importation of high-grade manganese ore were discontinued, numerous industries would be vitally affected. Of these the steel industry consumes by far the largest quantity of manganese.

Various ways have been suggested in which this situation may be alleviated in time of need. Some investigators propose the use of substitutes for manganese in steel making. Willcox [1] has recently suggested that aluminum, silicon, and titanium could be successfully used as deoxidizers in steel making to replace a large part of the ferromanganese. Willcox suggests also that by increased importation a reserve of high-grade manganese ore might be accumulated in this country sufficient to keep the steel industry in operation for perhaps a year should imports be stopped. The capital that would be tied up in such a reserve, however, is very large, and other remedies may be considered more feasible.

[1] Willcox, F. H., The significance of manganese in American steel metallurgy: Am. Inst. Min. Eng. Bull., February, 1917, pp. 199–207.

Newton,[1] who is at present engaged in a study of metallurgic problems concerning the use of manganese in the steel industry, proposes a modification of the basic open-hearth practice which would allow the extensive utilization of low-grade manganiferous iron ores. He suggests that instead of adding large quantities of ferromanganese or spiegeleisen to steel for deoxidizing at the end of the heat, a manganiferous pig iron containing about 3 or 4 per cent of manganese be used in the bath so that the deoxidation necessary at the end of a heat may be reduced to a minimum. It is believed that the presence of manganese in the bath throughout the heat will tend to prevent oxidation or the formation of ferrous oxide, and thus the addition of high-grade manganese alloys at the end of the heat would be economized. Various low-grade manganiferous ores could be used in the production of such high-manganese pig iron and the quantity of high-grade manganese ore required in the steel industry would be decreased. Newton suggests also that modifications might be made in steel-making practice which would permit the greater use of iron-manganese alloys containing manganese between the 20 per cent in spiegeleisen and the 80 per cent in ferromanganese, which are now considered essential.[2] These alloys also could be produced from manganiferous ores with the addition of varying amounts of high-grade manganese ore for the higher alloys.

With such possibilities in view it is very important that the attention of mining men should be directed toward the development of the reserves of both low-grade and high-grade manganiferous ore, especially the large reserves of manganiferous iron ore in the Cuyuna district of Minnesota.

Manganiferous ores of various kinds and grades are found in several parts of the United States. The Lake Superior iron-ore region contains extensive deposits of manganiferous iron ore, and in many mining districts of the West manganiferous silver ore is found in the upper oxidized portions of ore deposits containing precious and semiprecious metals. In the Lake Superior region the principal districts producing manganiferous iron ore are the Cuyuna, Penokee-Gogebic, and Iron River; the Cuyuna is by far the most productive. In the Western States manganiferous silver ore is being mined at Leadville, Colo., Pioche, Nev., Tombstone, Ariz., Silver City, N. Mex., and Philipsburg, Mont. Manganiferous silver ore is found also in other western mining regions, such as Butte and Neihart, Mont., and Lake Valley, N. Mex.; and manganiferous iron ore is more or less closely associated with the manganese ore of northern Arkansas

[1] Willcox, F. H., op. cit.; discussion of paper by Edmund Newton: Am. Inst. Min. Eng. Bull., June 1917, pp. 995-996.

[2] Newton, Edmund, personal communication.

and the Appalachian region. The manganiferous zinc residuum formed as a by-product in the smelting of New Jersey manganiferous and ferruginous zinc ores is also an important source of manganese.

The principal use for manganiferous ores in the West has been for flux in lead smelting. In some of the districts, however, such as Leadville, Colo., Philipsburg, Mont., and Tombstone, Ariz., some high-grade ore has been mined for the production of iron-manganese alloys. Much of the manganiferous iron ore of the Cuyuna range has likewise been used in the manufacture of iron-manganese alloys, the ore usually being mixed with foreign high-grade manganese ore. The Cuyuna ore is generally either too high in phosphorus or too high in silica to be used in making spiegeleisen without the admixture of other ores. A small tonnage, however, could probably be so used.

CUYUNA DISTRICT, MINN.

The Cuyuna district is in central Minnesota, about 90 miles west of Duluth. The productive area lies south of Mississippi River in Crow Wing County, but the ore-bearing formations are known to extend northeastward as far as the central part of Aitkin County and southwestward in Morrison and Todd counties.

Most of the ore deposits in the district consist of iron ore, the manganiferous iron ore bodies being confined mainly to the so-called north range, which forms the northern portion of the district, in Crow Wing County. A number of ore-bearing belts trend in a northeasterly direction through the north range, and bodies of iron ore and manganiferous iron ore are found at intervals along them, the former more abundantly in the southern part and the latter in the northern part. Iron ores and manganiferous iron ores are more or less closely associated, however, and may occur together in a single ore body. The ore-bearing belts are separated by areas of barren rock such as schist and slate.

The ore-bearing rocks consist of ferruginous chert and ferruginous slate near the surface and of cherty and slaty iron carbonate rock at a greater depth. Locally all these rocks carry manganese. The iron-ore deposits are inclosed in ferruginous chert and ferruginous slate near the bedrock surface and extend to depths depending upon the extent to which the rocks have been decomposed. They are generally very irregular in outline and grade into the inclosing rocks. Relatively barren masses of the associated rocks are common in the ore bodies. The deposits of manganiferous iron ore are similar in occurrence to the iron-ore deposits, but they are generally smaller and more irregular and do not extend as deep. The deepest manganiferous iron ore mine in the district has a depth of about 175 feet below the base of the glacial drift, and it will probably be found that most of the ore of these deposits is concentrated above this depth.

The productive deposits contain on an average between 200,000 and 500,000 tons each, though some contain considerably over 1,000,000 tons. The lower limit of workability of the ore bodies depends on a number of factors, such as grade and character of the ore, shape of the ore bodies, presence of included rock masses, depth of overburden, and amount of water. Some ore bodies containing less than 200,000 tons of ore can under favorable conditions be worked.

The character and mode of occurrence of the manganiferous iron ore depend upon the nature of the rocks with which it is associated. In deposits associated with ferruginous chert the ore is generally found along definite but locally rather thin layers, but in those occurring in slate the ore is scattered through wide zones. In many places the ore associated with ferruginous chert is finely crystalline and locally shows pure manganese minerals such as pyrolusite, psilomelane, and manganite in drusy cavities and veins, whereas that in ferruginous slate is commonly amorphous, although locally veins of manganese minerals are found. In deposits in ferruginous chert the entire beds are usually more or less impregnated with manganese and iron, although the metallic content shows a wide range from place to place. The ore in ferruginous slate, on the other hand, occurs in scattered nodules and irregular masses separated by ferruginous slate or its decomposition product, ferruginous clay.

There are two principal classes of manganiferous iron ore in the Cuyuna district—(1) low-phosphorus ores, which are usually high in silica, and (2) high-phosphorus ores, which are as a rule moderately low in silica. Low-phosphorus ores are commonly associated with cherty iron-bearing rocks and high-phosphorus ores with slaty iron-bearing rocks. This association, however, is not universal, and in some places high and low phosphorus ores occur together in the same series of rocks or even in the same deposit. Thus some mines produce only one class of ore, and in other mines ore bodies of both classes are closely associated. The ores of both classes show a great range in iron and manganese content, not only in different deposits but within short distances in the same deposit, especially across the strike of the formation. Layers low in manganese and high in iron may alternate with layers or lenses very high in manganese and low in iron. There are also variations along the strike of the beds, however, resulting locally in changes along the same bed from high-grade manganiferous iron ore to low-grade manganiferous iron ore or even to iron ore containing little or no manganese. In many deposits irregular masses of iron ore or of lean iron and manganese bearing rock are inclosed within manganiferous iron ore. These irregularities show that the grade of the ore varies from place to place and that it is difficult to maintain a uniform product from the mines. This difficulty is overcome in part by mixing ores from different parts of an ore body and in part by marketing several distinct grades of ore. Some mines offer as many as four grades of manganiferous iron ore.

The principal constituents of the ore are iron and manganese oxides, together with silica, which is found in the form of chert or quartz, and alumina, which occurs in clay and in several silicates. Iron and manganese carbonate are found locally in the ore, and iron silicates are common. Lime and magnesia occur in some ores and are probably present largely as carbonates or silicates. The principal gangue material is the country rock, such as ferruginous chert, ferruginous slate, or clay. Quartz veins occur in many of the ore bodies. With increasing depth ore bodies and associated rock grade into unaltered iron-bearing formation.

The content of manganese in the manganiferous iron ores ranges from 1 to 30 or 35 per cent, and the iron from 20 to 50 per cent or more. The silica usually ranges between 8 and 16 per cent in the low-phosphorus ores but is lower in the high-phosphorus ores. Phosphorus ranges generally from 0.06 to 0.10 per cent in the low-phosphorus ores and 0.15 to 0.25 per cent in the high-phosphorus ores. Water of hydration ranges from 6 to 12 per cent.

Below are given average cargo analyses of manganiferous iron ore from certain mines in the Cuyuna district:[1]

Average cargo analyses of manganiferous iron ore, dried at 212° F., from the mines of the Cuyuna district, Minn.

Mine.	Fe.	Mn.	P.	SiO_2.	Al_2O_3.	CaO.	MgO.	S.	Loss by ignition.
Armour No. 2	49.30	5.28	0.215	8.90	3.43	......	......	......	......
Cuyuna-Mille Lacs	37.71	21.22	.091	11.46	.95	0.82	0.47	Trace.	......
Do	39.02	17.06	.096	13.20	.42	.84	.67	Trace.	......
Do	37.39	12.91	.079	19.50	.22	.67	.63	Trace.	......
Do	40.02	8.96	.051	22.00	.18	.68	.60	Trace.	......
Ferro	29.29	22.29	.075	17.56	1.47	......	......	......	......
Hillcrest	43.811	9.880	.230	6.110	......	......	......	......	......
Algoma (Hoch)	32.26	19.50	.090	16.47	2.43	......	......	......	......
Mahnomen	40.00	14.00	.15	10.00	3.80	.22	.31	0.015	7.84
Do	46.00	8.00	.20	7.55	3.80	.22	.31	.015	9.84
Do	51.00	4.50	.19	6.10	3.70	.75	1.24	.029	9.90
Mangan No. 1	35.91	13.51	.099	22.29	2.99	.26	.37	.010	......
Meacham	46.58	4.42	.308	6.52	4.22	2.08	.55	......	12.02
Sultana	39.302	13.426	.170	8.536	3.50	.75	.50	.015	10.00
Do	37.74	14.68	.062	16.44	......	......	......	......	......

A total quantity of 363,334 gross tons of manganiferous iron ore, containing more than 5 per cent of manganese, has been shipped from the Cuyuna district to the end of 1916. The following table shows the annual shipments from the different mines:

[1] Analyses of Lake Superior iron ores, season 1916, pp. 8-11, Lake Superior Iron Ore Association, 1917.

Manganiferous iron ores shipped from the Cuyuna district, Minn., 1913 to 1916, inclusive, by mines, in gross tons.

Mine.	Ore containing 15 to 40 per cent manganese.				Ore containing 5 to 15 per cent manganese.				Total.
	1913	1914	1915	1916	1913	1914	1915	1916	
Cuyuna Mille Lacs	a26,200	55,000	35,221	......	......	......	......	90,000	206,421
Ferro	......	......	......	14,710	......	......	......	......	14,710
Hillcrest	......	......	......	......	......	......	......	a 2,712	2,712
Algoma (Hoch)	......	192	3,036	23,000	......	......	4,564	......	30,792
Mahnomen	......	......	......	......	......	......	......	43,000	43,000
Mangan, Nos. 1 and 2	......	......	......	......	......	......	......	30,329	30,329
Sultana	......	......	152	......	......	......	......	35,218	35,370
	26,200	55,192	38,409	37,710	......	......	4,564	201,259	363,334

a Percentage of manganese not stated.

As shown by the above table the production is rapidly increasing. In 1917 probably 14 or 15 mines will produce manganiferous iron ore.

The amount of manganiferous iron ore available in the district is only very imperfectly known. The following table shows estimated reserves of several grades of ore according to the Minnesota Tax Commission:[1]

Estimated reserves of manganiferous iron ore in the Cuyuna district, Minn.

Mn (per cent).	Fe (per cent).	Fe and Mn (per cent).	P (per cent).	Tons.
1.22	54.65	55.87	0.179	123,771
1.36	56.38	57.74	.159	3,122,031
3.53	53.69	57.22	.258	720,488
4.98	50.85	55.83	.350	644,750
5.90	49.15	55.05	.336	713,490
9.19	47.27	56.46	.058	468,566
10.99	46.46	57.45	.236	948,802
11.30	42.57	53.87	.226	1,939,417
11.44	43.49	54.93	.045	620,897
15.45	39.27	54.72	.090	408,878
15.96	43.26	59.22	.156	183,716
21.93	30.82	52.75	.070	100,000
				9,994,806

The estimates shown in the above table were made in 1913, before the possibilities of the extensive use of manganiferous iron ores were definitely realized. They include only ores whose metallic content is over 50 per cent. At the present time, however, the combined iron and manganese content of much of the ore that is shipped is less than 50 per cent. On the other hand, the estimates include a considerable quantity of material that is too low in manganese to constitute an important reserve of manganiferous ore. However, there has been much exploration work during the last three years,

[1] Appleby, W. R., and Newton, E., Preliminary concentration tests on Cuyuna ores: Minnesota School of Mines Exper. Sta. Bull. 3, p. 52, 1915. Minnesota Tax Commission Fourth Bienn. Rept., pp. 75 et seq. 1914.

and the known quantity of manganiferous iron ore of all grades has been increased greatly. There is no doubt that the Cuyuna district constitutes one of the most important sources of manganiferous ore in the United States.

OTHER LAKE SUPERIOR DISTRICTS.

Manganiferous iron ores are found in several other Lake Superior iron-ore districts besides the Cuyuna. Ores containing 5 per cent or more of manganese are being produced in the Penokee-Gogebic district of Michigan and Wisconsin and in the Iron River district of Michigan. In general relation these ores are similar to the manganiferous iron ore of the Cuyuna district, but their distribution is much more local and the quantity is comparatively small.

Besides manganiferous iron ores these districts, as well as the Marquette and Menominee districts of Michigan and the Mesabi district of Minnesota, produce considerable quantities of iron ore which contain between 1 and 3 per cent of manganese. Such ores can be used in the manufacture of high-manganese pig iron and should be reckoned among the sources of manganese.

APPALACHIAN REGION.

Small quantities of manganiferous iron ore have been produced intermittently at several localities along the Appalachian Valley from Vermont southward to Georgia. The manganiferous iron ore is generally associated with the brown iron ore or the high-grade manganese ore of the region,[1] and the conditions of occurrence and distribution are similar. The principal deposits are found along the west front of the Blue Ridge in Virginia, but many isolated deposits are known throughout the Appalachian Valley in Pennsylvania, Virginia, Tennessee, and Georgia.

The general features of most deposits of manganiferous iron ore along the Blue Ridge in Virginia and its southward extension in Tennessee and Georgia are very similar to those of the "mountain" brown ores. The shapes of the deposits vary with their structural associations; some occur in troughs, whereas others are in fault zones. The ores contain nodules of psilomelane with some manganite and limonite, embedded in clay resulting from the decomposition of the limestone and shale near by. No ores are known to persist 300 feet below the surface. In some of the deposits masses of manganiferous iron ore 50 or 60 feet long are known. Some deposits consisting of groups of large and small bodies or masses of manganiferous iron ore are many hundred feet in length and width.

[1] Harder, E. C., Manganese deposits of the United States, with sections on foreign deposits, chemistry and uses: U. S. Geol. Survey Bull. 427, pp. 27-102, 1910.

Manganiferous iron ore occurs also in association with the "valley" brown ore in Virginia and Tennessee and with the "Oriskany" brown ore in Virginia. Some deposits or parts of deposits of these ores are highly manganiferous. As in the Blue Ridge deposits, the ores are embedded in residual clay. They have been formed by surface concentration and replacement and do not extend far below the surface. In northwestern Virginia, in the New River region of southwestern Virginia, and in Shady Valley, Tenn., many such deposits are found. Until recently the demand for the ores has been slight, and many deposits have been abandoned. There is little doubt that a large quantity of manganiferous iron ore is available in the Appalachian region.

The iron and manganese oxides that make up the manganiferous iron ore are clearly distinguishable in many of the deposits. Manganese oxides, such as psilomelane or pyrolusite, occur as irregular pockets in the iron ore or small lenses of iron and manganese oxides may be found interlayered or irregularly intermixed. There are other deposits, however, in which the iron and manganese oxides are indistinguishable from each other, and the mixture forms a homogeneous black or brownish-black ore.

Much of the manganiferous iron ore of the Appalachian region, such as that occurring along the Blue Ridge, is very siliceous. Some shipments, however, show a high content in metal. Analyses of some of the ores are given below.

Analyses of manganiferous iron ore from the Appalachian region.

Mn.	Fe.	P.	SiO_2.
8.22	41.12	0.260	14.83
10.18	40.10	.536	10.52
25.09	29.17	.155	....
30.32	23.90	.100	6.37
36.48	15.83	.089	7.56
44.31	12.32	.101	5.47

The following table shows the production of manganiferous iron ore in the eastern part of the United States,[1] including the Appalachian region:

Manganiferous iron ore produced in eastern United States, 1887–1917, in gross tons.

	Virginia.	Other Eastern States.
1887	1,025	[a] 726
1888	....	[b] 1,096
1892	3,000	....
1893	1,188	[c] 20
1897	....	[d] 1,200
1898	....	[e] 100
1901	....	[c] 20
1902	3,000	....
1903	2,802	....
1908	274	....
1909	305	....
1910	301	....
1911	1,007	....
1912	1,567	....
1914	1,363	[f] 410
1915	1,944	[g] 826
1916	37,729	[h] 5,065
	55,505	9,463
1917 (estimated)	45,000	750

[a] Georgia, Maine, and Vermont.
[b] North Carolina, South Carolina, Tennessee, and Vermont.
[c] North Carolina.
[d] Vermont.
[e] Pennsylvania.
[f] South Carolina.
[g] Georgia and Tennessee.
[h] Georgia, Pennsylvania, and Tennessee.

NORTHERN ARKANSAS.

During the past 12 years several thousand tons of manganiferous iron ore have been produced annually in northern Arkansas. Practically all this ore has come from one mine in the southern part of the district north of Batesville. The ore is found in horizontal strata, known as the Cason shale, which lie unconformably upon the next lower formation, the unconformity representing a long period of erosion. The strata consist of dark-red sandy shale 10 to 15 feet thick, containing a few layers of dark quartzite. In places the entire formation is heavily impregnated with iron and manganese oxides, and the shaly layers contain an abundance of small flattened buttons of manganiferous iron ore lying parallel to the stratification. The buttons range from half an inch to 2 inches in the longer diameter and are from a quarter to half an inch thick. Locally they merge into one another and form thin horizontal layers. The buttons are closely grouped, and generally make up more than half of the rock mass. They are more abundant in the upper part of the bed than in the lower part. Where many are present they constitute a low grade manganiferous iron ore.

The part of the Cason shale which contains manganiferous iron ore occupies a considerable area in the southern part of the Batesville district, and doubtless large quantities of this low grade material are available. As the ore has the nature of an original sediment and is not secondarily concentrated by surface weathering, it may occur in the Cason shale underneath the hills as well as along the outcrop. In the northern part of the Batesville district this bed carries high grade manganese ores.[1]

[1] Harder, E. C., Manganese deposits of the United States, with sections on foreign deposits, chemistry, and uses: U. S. Geol. Survey Bull. 427, pp. 102–118, 1910.

The following analyses show the composition of the northern Arkansas manganiferous iron ore:

Analyses of northern Arkansas manganiferous iron ore.

Fe.	Mn.	P.	SiO_2.	Moisture.
4.88	34.64	0.580	25.65	....
8.45	38.30	.380	....	....
10.75	41.08	.467	....	....
12.50	43.12	.339	1.54	....
15.70	35.40	.735	4.35	16.30
18.80	33.21	.194	6.05	15.10
21.63	24.31	.252	14.82	....
23.40	29.57	.452	5.10	19.00

Below is given the total production of manganiferous iron ore in Arkansas.

Manganiferous iron ore produced in Arkansas, 1893–1916, in gross tons.

1893	160	1909	3,325	1915	3,355
1904	600	1910	5,030	1916	3,869
1905	3,321	1911	2,177		51,888
1906	8,900	1912	1,332		
1907	4,133	1913	9,650		
1908	4,066	1914	1,970		

WESTERN UNITED STATES.

The manganiferous ores associated with precious and semiprecious metal deposits in the mining regions of the western United States are principally of two kinds—those containing a large proportion of both manganese and iron oxides and those containing manganese oxides, with little or no iron oxide. Ores of the first class are by far the most abundant and include those of Leadville, Colo.; Pioche, Nev.; and Silver City, N. Mex. Manganiferous ores containing little or no iron are found at Philipsburg and Butte, Mont., and at Tombstone, Ariz. Nearly all the ores contain small amounts of other metals, such as silver, gold, lead, zinc, and copper.

The manganese content of the manganiferous ores shows a great range. Where the proportion of the combined manganese and iron oxides is fairly high the ore may be used in the manufacture of spiegeleisen. Elsewhere, however, such impurities as silica, alumina, and lime are present in large quantities. Most of the ores that contain little or no iron contain a large proportion of the impurities mentioned above. Locally, however, as at Philipsburg, some ore that is fairly high in manganese is found. Thus, in the Western States, all gradations from manganese ore to low-grade manganiferous material are known. If silica and other impurities could be removed from such ores by cheap and efficient methods of concentration, large quantities would become available at Philipsburg, Butte, and other localities. The concentration would yield a high-grade manganese product, such as could not be produced from manganiferous ores containing iron.

Of the manganiferous ores containing both manganese and iron, those of Leadville, Silver City, and Pioche are of considerable value. The Leadville ores have for many years been mined in large quantities for use as flux and in smaller quantities for the manufacture of spiegeleisen. Those of Silver City and Pioche have also been used largely for flux in past years, but at the present time considerable ore is being mined at Silver City for use in the manufacture of spiegeleisen. The Leadville and Silver City ores are smelted at Pueblo, Colo.

The manganiferous ores are found in the upper oxidized portions of deposits containing silver, lead, gold, copper, zinc, and other metals. With increasing depth the oxides grade into unaltered manganese or iron carbonates or silicates, which form the gangue minerals associated with the sulphides of the other metals. Only the oxidized parts of deposits have been used for their iron or manganese content, as the unaltered gangue minerals are usually of too low grade. The depth of the oxidized zone varies from place to place.

A few average analyses of manganiferous ore from Leadville and Silver City are given below.

Analyses of manganiferous ore from Leadville, Colo., and Silver City, N. Mex.

Locality.	Fe.	Mn.	P.	SiO_2.	Al_2O_3.	CaO.	Moisture.
Leadville	17.05	33.14	0.061	7.97	1.32	1.18	14.80
Do	22.75	27.30	.115	6.50	1.53	1.84	14.10
Do	26.99	23.52	.060	4.31	1.21	1.55	14.96
Do	29.70	19.60	.052	10.60	2.25	1.84	14.28
Silver City	37.00	17.00	.015	9.00	....	5.00	....

The following table shows the production of manganiferou ores in the western part of the United States as far as has been recorded:

Manganiferous ores produced in the western United States, 1885–1916, in gross tons.[a]

Year.	Colorado.		Other States.	Year.	Colorado.		Other States.
	Used in the manufacture of iron-manganese alloys.	Used for flux.			Used in the manufacture of iron-manganese alloys.	Used for flux.	
1885			[b] 4,263	1902	13,275	194,132	
1886		[c] 60,000		1903	14,856	179,205	
1887		[c] 60,000		1904	17,074	105,278	
1888		[c] 60,000		1905	45,837	81,738	
1889		64,987		1906	32,400	([d])	
1890	6,397	51,840		1907	67,514	32,197	[e] 7,000
1891	964	79,511		1908	15,973	35,581	
1892	2,942	62,309		1909	12,905	52,119	
1893	5,766	55,962		1910		55,770	
1894	7,022	31,687		1911		41,753	
1895	13,464	54,163		1912		48,618	
1896	9,072	138,079		1913		49,753	
1897	16,519	149,502		1914	2,100	37,781	
1898	18,848	99,651		1915	15,956	14,965	[f] 106,005
1899	29,355	79,855		1916	16,263	90,850	[g] 150,642
1900	43,303	188,509					
1901	62,385	228,187			470,190	2,483,982	267,910

[a] Hewett, D. F., Manganese and manganiferous ores: U. S. Geol. Survey Mineral Resources, 1914, pt. 1, p. 175, 1916, and corresponding chapter for 1916 (in preparation).
[b] Montana.
[c] Contains some Montana ore.
[d] Not recorded.
[e] New Mexico.
[f] Arizona, Nevada, and Utah.
[g] Arizona, California, Montana, Nevada, New Mexico, Utah, and Washington.

Besides the districts which have been mentioned there are doubtless in many parts of the West areas containing appreciable quantities of manganiferous ores. Many such localities have been reported during the last few years, and some of them have been investigated by the United States Geological Survey in the summer of 1917. There are probably others that have thus far escaped observation.

SUMMARY.

There are in the United States large quantities of manganiferous ores containing varying amounts of manganese. A very small proportion of these can be used in the production of high-grade iron-manganese alloys, but a large proportion can be used for lower-grade alloys, and nearly all can be used in making high-manganese pig iron. Compared with the manganiferous ores, the reserves of high-grade manganese ores in this country are insignificant. Hence, although a search for manganese ore is desirable, a more promising solution of the manganese problem would seem to lie in the direction of the utilization of low-grade manganiferous ores. Up to the present time the use of these ores has been very slight. Until a few years ago they were considered to have little value and were mined only incidentally. In the West manganiferous ores would not be mined were it not for their association with ores of other metals.

There are several ways in which the utilization of manganiferous ores may be brought about: (1) It has been suggested that by methods of concentration resulting in the elimination of iron, silica, or other constituents a product high in manganese might be derived from them. Such concentration has been attempted locally but with very little success, owing mainly to the intimate mixture which manganese generally forms with associated materials. (2) The steel-making practice might be changed so that more spiegeleisen and less ferromanganese would be used for deoxidizing. By the addition of small quantities of high-grade manganese ore much of the manganiferous iron ore could be used in the manufacture of spiegeleisen. (3) The most effective solution, however, as has previously been suggested, seems to be to so change the practice in the manufacture of basic open-hearth steel as to make possible the use of high-manganese pig iron. Experimentation along this line is extremely desirable. The successful application of such a change would make large reserves of manganiferous iron ore commercially available and would greatly decrease the quantity of high-grade manganese ore consumed.

127972°—19——14

QUICKSILVER.[1]

By F. L. Ransome.

INTRODUCTION.

Mining for quicksilver[2] (mercury) in the United States began in California in 1848, and the total production to the end of 1917 is 2,305,130 flasks, valued at $108,708,078. Large as this sum is it is only about one-ninth of the value of the lead produced in this country to the end of 1915, or about one-sixteenth of the value of the silver, one thirty-third of the value of the copper, or one thirty-fifth of the value of the gold mined prior to 1917. Thus quicksilver mining is a comparatively small industry in this country.

Up to 1882 the mines of California supplied all the quicksilver produced in the United States. Texas, which began production in 1899 with 1,000 flasks, now ranks as the second quicksilver mining State in the Union, with an output of 10,791 flasks in 1917. Nevada, which now holds third place, began production in 1903, reached its acme with 2,550 flasks in 1912, and yielded 997 flasks in 1917. Oregon, with 388 flasks in 1917, ranks fourth, and much smaller quantities are obtained from Arizona, Idaho, and Washington. From 1903 to 1907 considerable quicksilver was produced in Utah, the annual output from that State amounting to 1,133 flasks in 1905, but Utah now produces no quicksilver.

The world's production of quicksilver in 1917 is estimated at 122,592 flasks, of which the United States produced 36,159 flasks, Italy 29,300 flasks, Spain 25,133 flasks, and Austria-Hungary probably about 27,500 flasks.

USES.

As everybody knows, quicksilver is used in thermometers and barometers, but the quantity consumed annually in the United States in the manufacture of such instruments is less than 2 per cent

[1] The chapter on quicksilver for this bulletin was originally undertaken by Mr. H. D. McCaskey. Finding, however, that other duties were preventing its completion, he turned over the task to me in September, 1918, with such notes as he had prepared for his manuscript.—F. L. R.

[2] "Quicksilver" and "mercury" are two names for the same metal and to some extent are interchangeable. "Quicksilver," however, is the term commonly used in mining and commerce, while "mercury" belongs particularly to the language of science and especially of chemistry. In the industrial arts the two words have nearly equal currency.

of the total quantity produced. Mercury is a constituent of many drugs and chemicals, including calomel and corrosive sublimate, and mercuric oxide and mercury salts are used in the manufacture of certain chemicals of which the mercury itself does not form a part. For example, in one process of producing glacial acetic acid acetylene is oxidized with mercuric oxide, the same lot of mercury being used repeatedly. Mercury is used also in making phthalic anhydride and phthalic acid, organic compounds which are employed in the dye industry but which themselves contain no mercury. The use of mercury fulminate as a detonator has expanded enormously with the increase in the variety and efficiency of the high explosives now manufactured for industrial and military purposes, and, although primers have been made of other materials, especially for small arms, no substitute has found general acceptance. Quicksilver is now used extensively in the manufacture of antifouling ship-bottom paint. The consumption of quicksilver in gold-dredging and other placer operations is still large. In gold-quartz mills, however, the amalgamation process has been largely supplanted by cyanidation. Among the varied uses to which quicksilver is put may be mentioned also its employment in dental amalgams; in the manufacture of laboratory air pumps and other scientific instruments; in thermostats, gas governors, and similar appliances; in mercury-vapor electric lamps; in compounds for preventing scale in steam boilers; in cosmetics; in certain electrolytic processes for the manufacture of chlorine, caustic soda, and picric acid; in primary batteries, electrolyzers, rectifiers, and other electrical equipment; and in felt making.

ORES.

Most quicksilver ores are of rather simple mineral composition. About 25 mercurial minerals are known, but most of these are rare, and some of them contain quicksilver only as a minor constituent. Over 95 per cent of the quicksilver produced in the United States comes from the bright cochineal-red sulphide of mercury, known in its natural form as the mineral cinnabar. Pure cinnabar contains 86.2 per cent of quicksilver. Minor sources of quicksilver include metacinnabar, which has the same composition as cinnabar but is dark gray or black, and native quicksilver, which generally occurs in little globules but in some mines fills cavities of considerable size. The cinnabar in quicksilver ores is usually associated with pyrite or marcasite and less generally with the sulphide of antimony, stibnite. The commoner nonmetallic constituents of the ore are quartz, chalcedony, opal, calcite, mixed carbonates of calcium, magnesium, and iron, and barite. Many quicksilver ores contain also small quantities of an oily or asphaltic hydrocarbon, and some carry free sulphur.

No quicksilver ores that are mined on a large scale consist exclusively of pure cinnabar. The richest that are extensively worked are those at Almaden, Spain, where the average yield in 1917 was slightly less than 7 per cent. Probably the lowest tenor in ores that are successfully mined is found on the Pacific coast of the United States. The average yield of the California ores during the last two years was 0.38 per cent.

METALLURGY.

The ores of quicksilver, unlike those of most metals that are won by smelting, are without exception in this country treated at the mines, and the liquid metal is shipped as a finished commercial product in iron bottles or flasks containing 75 pounds each. A moderate heat, about 360° C., is enough to vaporize and decompose cinnabar, and the quicksilver is obtained directly by condensation in suitable chambers through which the fumes from the furnace are conducted. There are two classes of reducing apparatus—furnaces and retorts. In most furnaces the ore is exposed to the direct action of the flame, the volatile products of combustion, with more or less dust, mingle with the vapors of sulphur and mercury driven from the ore, and all pass together through condensers. The operation is in general continuous. In retorts, on the other hand, the ore is heated in a closed iron vessel, out of contact with the flame, and only those volatile constituents that are released from the ore pass into the condensing apparatus. In most retorts the operation is intermittent.

FORM OF QUICKSILVER ORE BODIES.

Quicksilver ore bodies are notoriously irregular in form, and probably for no other group of metalliferous deposits is prediction or quantitative estimation more difficult. By far the greater number of quicksilver ore bodies that have been or are being worked in the United States are irregular lenses, pipes, or podlike masses with few or no definite surfaces of demarcation separating them from the inclosing rocks. Where several ore bodies occur they are usually arranged along a principal zone of fissuring and may have one distinct wall, generally marked by a seam of claylike material, or gouge, produced by the crushing and grinding of the rock along one of the fissures. The ore masses may consist of porous rock through which the cinnabar or other quicksilver minerals are scattered in small crystal particles, or may be made up of rock that is traversed by many irregular veinlets or stringers, in which occur most or all of the valuable minerals, the rock between the stringers being barren.

OCCURRENCE.

The ores of quicksilver, like those of most other metals, show on the whole a close association with igneous rocks and with zones of fissuring. Their deposition, more commonly than that of other metals, with the possible exception of antimony, was associated with volcanism as opposed to plutonic igneous activity and occurred comparatively near the surface. It follows that quicksilver deposits as a rule are found in regions of Tertiary and Quaternary volcanic activity which have not been subjected to long and deep erosion, that they are more likely to occur in the younger geologic formations than in the older ones, and that as a class they do not extend to great depth. It must be noted, however, that there are some conspicuous exceptions to these generalizations. Although most quicksilver deposits are in regions of geologically late volcanic eruptions, it is probable that ores of quicksilver were deposited also during or soon after epochs of similar igneous activity in the older geologic periods but that many of them have been removed by erosion. Some of the deposits which are in the older rocks and which do not appear to be related to Tertiary or later volcanic eruptions may have had such earlier origin.

It is entirely in accord with the general association of quicksilver ores with volcanic activity that the quicksilver deposits of the United States are found in the western part of the country, where the products of Tertiary and later vulcanicity abound and where numerous hot and thermal springs testify to the comparative recency of much of the igneous activity.

In California the principal deposits occur in the Coast Ranges within a belt about 400 miles long that extends from Santa Barbara on the southeast to Ukiah on the northwest. The maximum width of this belt is about 75 miles. The known deposits within this area are numerous. About 25 of these are at present productive, but it is estimated that at least three times that number of mines which were productive in the past are now idle. A comparatively small number are prospects, from which no production has yet been recorded.

With a few exceptions the deposits of the main quicksilver belt in California are in rocks of the Franciscan formation, probably of Jurassic age, or in the serpentine which is so abundant and characteristic an associate of these rocks. Probably the greater number are in the serpentine. Others are in sandstone, generally near the serpentine, and still others are in thin-bedded siliceous rocks known as radiolarian chert.

The most productive mine in California at present is the New Idria, in San Benito County, which in 1917 yielded 11,000 flasks out of a total for the State of 23,938 flasks and for the United States of 36,159 flasks. The total production of California to the end of 1917 is 2,210,852 flasks, valued at $102,851,913.

In Oregon cinnabar is widely distributed, but only one deposit, a metallized fissure zone in andesite at Blackbutte, in Lane County, is at present commercially productive.

In Washington cinnabar has been found at a few localities in Chelan, Kittitas, and Lewis counties. None of the deposits has yet proved to be of economic importance.

Nevada contains many widely scattered deposits of quicksilver ore, no one of which has yet been worked on an extensive scale, although a few of them have been fairly productive for short periods. The Nevada quicksilver ores occur in rhyolite of Tertiary age and in limestones or associated sedimentary beds of various ages from Paleozoic to Mesozoic. The production in 1916 was 2,198 flasks, valued at $276,706, and in 1917 it was 997 flasks, valued at $105,004.

In Arizona most of the known quicksilver deposits occur in zones of fissuring or shearing in pre-Cambrian schist.

In Texas the principal deposits are in the Terlingua district, in Brewster County, about 75 miles south of Alpine. The ore occurs along fissure zones in Cretaceous limestones and shales, generally in proximity to bodies of intrusive rock. These mines yielded in 1917 10,791 flasks of quicksilver, valued at $1,136,508, and in 1916 6,306 flasks, valued at $793,862. The production of Texas from the beginning of operations to the end of 1917 is 76,200 flasks, valued at $4,680,295.

STATISTICS OF PRODUCTION, PRICES, IMPORTS, AND EXPORTS.

The tables which follow have been taken from the Geological Survey's report on the production of quicksilver in 1917, which the reader should consult for more detailed information than can be presented in this summary.

Quicksilver produced in the United States, 1850–1917.

[In flasks of 76.5 pounds to June, 1904; subsequently in flasks of 75 pounds.]

Year.	Flasks.	Price per flask.	Value.	Year.	Flasks.	Price per flask.	Value.
1850	7,723	$99.45	$768,052	1885	32,073	$30.75	$986,245
1851	27,779	66.93	1,859,248	1886	29,981	35.50	1,064,325
1852	20,000	58.33	1,166,600	1887	33,825	42.375	1,433,334
1853	22,284	55.45	1,235,648	1888	33,250	42.50	1,370,625
1854	30,004	55.45	1,663,722	1889	26,484	45.00	1,191,780
1855	33,000	53.55	1,767,150	1890	22,926	52.50	1,203,615
1856	30,000	51.65	1,549,500	1891	22,904	45.25	1,036,406
1857	28,204	48.73	1,374,381	1892	27,993	40.71	1,139,595
1858	31,000	47.83	1,482,730	1893	30,164	36.75	1,108,527
1859	13,000	63.13	820,690	1894	30,416	30.70	933,771
1860	10,000	53.55	535,500	1895	36,067	37.04	1,335,922
1861	35,000	42.05	1,471,750	1896	30,765	34.96	1,075,544
1862	42,000	36.35	1,526,700	1897	26,691	37.28	995,040
1863	40,531	42.08	1,705,544	1898	31,092	38.23	1,188,647
1864	47,489	45.90	2,179,745	1899	30,454	47.70	1,452,656
1865	53,000	45.90	2,432,700	1900	28,317	44.94	1,272,566
1866	46,550	53.13	2,473,202	1901	29,727	48.46	1,440,570
1867	47,000	45.90	2,157,300	1902	34,291	43.20	1,481,371
1868	47,728	45.90	2,190,715	1903	35,634	45.29	1,613,864
1869	33,811	45.90	1,551,925	1904	35,315	43.50	1,536,203
1870	30,077	57.38	1,725,818	1905	30,534	36.22	1,105,941
1871	31,686	63.10	1,999,387	1906	26,083	39.50	1,030,279
1872	31,621	65.93	2,084,773	1907	21,554	39.60	853,538
1873	27,642	80.33	2,220,482	1908	19,752	44.17	872,446
1874	27,756	105.18	2,919,376	1909	21,075	45.45	957,859
1875	50,250	84.15	4,228,538	1910	20,601	46.51	958,153
1876	72,716	44.00	3,199,504	1911	21,256	46.01	977,989
1877	79,395	37.30	2,961,434	1912	25,064	42.05	1,053,941
1878	63,880	32.90	2,101,652	1913	20,213	40.23	813,171
1879	73,684	29.85	2,199,467	1914	16,548	49.05	811,680
1880	59,926	31.00	1,857,706	1915	21,033	85.80	1,804,631
1881	60,851	29.83	1,815,185	1916	29,932	125.89	3,768,139
1882	52,732	28.23	1,488,624	1917	36,159	105.32	3,808,266
1883	46,725	28.75	1,343,344				
1884	31,913	30.50	973,347		2,305,130	....	108,708,078

Quicksilver imported and entered for consumption in the United States, 1908–9117.[a]

Year.	Quantity (pounds).	Value.	Year.	Quantity (pounds).	Value.
1908	15,113	$8,216	1913	171,653	$75,361
1909	15,968	8,203	1914	614,869	271,984
1910	667	381	1915	421,884	282,752
1911	471,944	251,386	1916	424,396	515,919
1912	82,706	39,920	1917	390,494	449,032

[a] Prepared by J. A. Dorsey from records of the Bureau of Foreign and Domestic Commerce, Department of Commerce.

Quicksilver exported from the United States, 1906–1917.[a]

Year.	Quantity (flasks of 75 pounds).	Value.	Year.	Quantity (flasks of 75 pounds).	Value.
1908	2,996	$124,960	1913	1,140	$43,574
1909	6,802	266,243	1914	1,446	70,753
1910	1,923	91,077	1915	3,372	225,509
1911	291	13,995	1916	8,880	670,475
1912	310	13,360	1917	10,778	998,470

[a] Prepared by J. A. Dorsey from records of the Bureau of Foreign and Domestic Commerce, Department of Commerce.

Prices of domestic quicksilver at San Francisco, 1915–1917.

[Per flask of 75 pounds.]

Month.	1915	1916	1917	Month.	1915	1916	1917
January	$51.90	$222.00	$81.00	July	$95.00	$81.20	$102.00
February	60.00	295.00	126.25	August	93.75	74.50	115.00
March	78.00	219.00	113.75	September	91.00	75.00	112.00
April	77.50	141.60	114.50	October	92.90	78.20	102.00
May	75.00	90.00	104.00	November	101.50	79.50	102.50
June	90.00	74.70	85.50	December	123.00	80.00	117.42

FUTURE OF THE QUICKSILVER-MINING INDUSTRY IN THE UNITED STATES.

An appraisal of the quicksilver resources of the United States based on actual measurements and estimates of the quantity of ore available in individual deposits presents insuperable practical difficulties. The best that can be done is to reach some rough conclusion from the history of the industry and from general knowledge and impressions of its present status and of the condition of known deposits. It is also necessary to take into account the probability of the discovery of new deposits and of improvements in metallurgy.

Records show that quicksilver mining in the United States has generally declined since 1877, when the domestic production reached its acme, with 79,395 flasks. The output sank in 1914 to 16,548 flasks. Although not uniformly retrogressive, the decline was on the whole fairly regular and on this account the more ominous. The price has not declined at the same rate as the output. In 1877, the year of maximum yield, quicksilver was worth only $37.30 a flask. In 1890 it had risen to $52.50 a flask, and in 1914 it was $49.05 a flask. Production has failed to respond to the stimulation of moderate increases in price, and the conclusion that the supply of ore has on the whole been decreasing in tenor and available quantity since 1877 appears to be warranted by the historical record. It is true that under the influence of unprecedented high prices during the recent war years the production rose to 36,159 flasks in 1917. This increase, however, was not accompanied by the discovery of any large new sources of supply, and that the domestic output of quicksilver must decline from the point reached in 1917 appears inevitable.

A wide survey of the known quicksilver deposits of the country confirms the conclusion drawn from historical and statistical data. The deposits, with few exceptions, are not large, most of them probably do not extend to great depth, and many of them are decidedly of superficial character. Even if the ore at certain localities does continue to a depth of 1,000 feet or more, some of the deeper ore bodies, in consequence of their irregularity and lack of continuity, are likely to remain undiscovered. Some of the mines that are at present the most productive have in all probability passed their period of greatest yield, although there is still a possibility that the discovery of new ore bodies may restore them temporarily to something like their former activity.

There are in California a large number of old quicksilver mines which have been productive but which have lain idle for years and which even the unprecedented prices obtainable for quicksilver during the last three years failed to revivify. Some of these are probably exhausted. Others contain ore bodies or at least material that carries some quicksilver; and these mines will some day be reopened. For most of them, however, this is not likely to happen in the near future under any conditions that can now be foreseen. They will probably remain undisturbed until the higher grade and more accessible deposits of the world are exhausted.

During the last 20 years comparatively few new quicksilver deposits have been found, and only four or five of these have produced more than a few hundred flasks each. Of the total domestic production of 36,159 flasks in 1917 less than 600 flasks came from new mines opened during the war period, and not one of these promises to develop a production of 1,000 flasks or more annually. The exploitation of the Terlingua district represents a notable modern addition to the known quicksilver resources of the country. Other regions capable of as great or greater production may be awaiting discovery, but as years pass the possibility is diminishing, and it is now hardly probable that any other locality with the potential productivity of the Terlingua district will be discovered in the United States.

It appears on the whole that quicksilver mining in the United States must be regarded as a declining industry, in which, however, there is still opportunity for individual success not only in working known deposits but in discovering and developing new ones. During the next 10 years the annual output may be expected to fall to 15,000 flasks or less. Prices of course will affect the output, but they can not change the physical conditions upon which production fundamentally depends. The high prices obtainable during the war nearly tripled the annual output, but the same or even higher prices could not again produce the same result.

The price of quicksilver in the United States during the next few years will depend upon so many uncertain factors that prediction is extremely hazardous. Among the determining conditions may be mentioned changes in the uses of quicksilver, the cost of labor and supplies, the quantity and price of foreign quicksilver available, and tariff legislation. The decline of our own production, of course, makes for higher prices. With the coming of peace there will be less quicksilver required for war purposes, although some of the modern applications that sprang from the exigencies of war are likely to persist. It is believed that the industrial consumption of quicksilver will be greater after the war than it was before and will continue to increase until diminishing supply and rising price force the extensive employment of substitutes. Quicksilver can undoubtedly be produced more cheaply abroad, especially in Spain, than in the United States, but it is doubtful whether this country will in the near future be deluged with foreign quicksilver to the extent feared by some domestic producers. Self-interest alone on the part of importers and foreign dealers would seem to preclude an attempt to lower the price in this country to anything near the cost of production in Spain.

The plan of attempting to maintain the quicksilver-mining industry in the United States by a high duty on imported metal has many advocates among the quicksilver producers, whose representatives at a hearing held by the Tariff Commission in San Francisco in June, 1918, asked for a duty of $35 a flask in addition to the present 10 per cent ad valorem. Such a duty would increase the profits of some of the larger mines but would not transform a declining industry into a growing and self-supporting one. It is doubtful whether there is any wisdom in attempting to foster quicksilver mining by a high import duty whose effect would be to levy a tax on all users of quicksilver for the benefit of a small group of producers, and it is still more doubtful whether the people of the United States would submit to this tax. It has been urged that as quicksilver is essential in warfare the mining of quicksilver should be stimulated by tariff protection. This might be an excellent argument were our quicksilver supplies without limit, but inasmuch as they are in process of exhaustion it is difficult for one who looks at the question impartially to see why the Government should hasten the approach of that day when there shall be no more quicksilver ore to mine rather than purchase quicksilver where it can be bought cheaply, store it as an immediately available reserve supply against the next war, which it is hoped may never come, and rely as a final resource upon those mines in which some ore, that would have been taken out under sufficient governmental encouragement, may yet remain to be of service in a great emergency.

BIBLIOGRAPHY.

Compiled under the direction of G. M. Wood.

MINERALS COVERED.

The following bibliography includes only publications issued by the United States Geological Survey concerning deposits of the minerals considered in this bulletin, a list of which is given below. It does not include purely statistical reports, which will be found in the Survey's annual volumes entitled "Mineral Resources of the United States." The entries are grouped under the headings given in the list, and those in each group are arranged primarily in alphabetic order by names of authors and secondarily, under each author, in chronologic order.

	Page.
Alaska's mineral supplies	1
Antimony. *See* Rarer metals.	
Arsenic. *See* Rarer metals.	
Asbestos	8
Barium and strontium	9
Bauxite and aluminum	9
Bismuth. *See* Rarer metals.	
Chromite	10
Clay and clay products	10
Coal	12
Copper	23
Fluorspar	26
Graphite	27
Grinding and polishing materials	28
Gypsum	28
Iron	30
Lead	33
Limestone and lime	36
Magnesite	37
Manganese and manganiferous iron ores	38
Mica, monazite, and lithium minerals	38
Molybdenum. *See* Rarer metals.	
Nickel. *See* Rarer metals.	
Nitrates	39
Petroleum	39
Phosphate rock	45
Platinum	47
Portland cement	47
Potash	48
Quicksilver	50
Rarer metals	50
Salt, bromine, and calcium chloride	54
Sand and gravel	55
Sulphur and pyrite	55
Talc and soapstone	56
Tin. *See* Rarer metals.	
Tungsten. *See* Rarer metals.	
Vanadium. *See* Rarer metals.	
Zinc	56

ALASKA'S MINERAL SUPPLIES.

ATWOOD, W. W., Mineral resources of southwestern Alaska: Bull. 379, pp. 115–152, pls. 5–6, 1909.

——— Geology and mineral resources of parts of the Alaska Peninsula: Bull. 467, pp. 95–131, 1911.

BECKER, G. F., Reconnaissance of the gold fields of southern Alaska: Eighteenth Ann. Rept., pt. 3, pp. 60–86, 1897.

Blackwelder, Eliot, Reconnaissance on the Pacific coast from Yakutat to Alaska River: Bull. 314, pp. 82–88, 1907.

Brooks, A. H., A reconnaissance from Pyramid Harbor to Eagle City, Alaska, including a description of the copper deposits of the Upper White and Tanana rivers: Twenty-first Ann. Rept., pt. 2, pp. 373–383, 1900.

——— An occurrence of stream tin in the York region, Alaska: Mineral Resources, 1900, pp. 267–271, 1901.

——— The coal resources of Alaska: Twenty-second Ann. Rept., pt. 3, pp. 515–571, 1901.

——— Placer gold mining in Alaska in 1902: Bull. 213, pp. 41–48, 1903.

——— Stream tin in Alaska: Bull. 213, pp. 92–93, 1903.

——— Placer mining in Alaska in 1903: Bull. 225, pp. 43–59, 1904.

——— Placer mining in Alaska in 1904: Bull. 259, pp. 18–31, 1905.

——— The mining industry in 1905: Bull. 284, pp. 4–9, pl. 2, 1906.

——— The mining industry in 1906: Bull. 314, pp. 19–39, pl. 1, 1907.

——— The Kougarok region: Bull. 314, pp. 164–181, 1907.

——— The Circle precinct: Bull. 314, pp. 187–204, 1907.

——— The distribution of mineral resources in Alaska: Bull. 345, pp. 18–29, pl. 1, 1908.

——— The mining industry in 1907: Bull. 345, pp. 34–53, 1908.

——— The mining industry in 1908: Bull. 379, pp. 28–62, 1909.

——— Mineral resources of Alaska: Bull. 394, pp. 172–203, pl. 12, 1909.

——— The mining industry in 1909: Bull. 442, pp. 33–46, 1910.

——— Alaska coal and its utilization: Bull. 442, pp. 47–100, pl. 1, 1910.

——— The mining industry in 1910: Bull. 480, pp. 26–42, 1911.

——— Geologic features of Alaskan metalliferous lodes: Bull. 480, pp. 43–93, pls. 1–6, 1911.

——— The mining industry in 1911: Bull. 520, pp. 23–44, 1912.

——— Gold deposits near Valdez: Bull. 520, pp. 108–130, pl. 6, 1912.

——— The mining industry in 1912: Bull. 542, pp. 30–51, 1913.

——— [Placer mining on Seward Peninsula]: Water-Supply Paper 314, pp. 269–303, 1913.

——— The mineral deposits of Alaska and the Alaskan mining industry in 1913: Bull. 592, pp. 18–74, pls. 1–2, 1914.

——— The Chisana placer district, Alaska: Bull. 592, pp. 309–320, pls. 13–14, 1914.

——— The mining industry in 1914: Bull. 622, pp. 40–68, 1915.

——— The future of gold placer mining in Alaska: Bull. 622, pp. 69–79, 1915.

——— The Alaskan mining industry in 1915: Bull. 642, pp. 16–71, pl. 1, 1916.

——— Preliminary report on the Tolovana district: Bull. 642, pp. 205–209, pl. 9, 1916.

——— Antimony deposits of Alaska: Bull. 649, 67 pp., 1916.

——— The Alaskan mining industry in 1916: Bull. 662, pp. 1–62, pls. 1–4, 1917.

Brooks, A. H., and others, Reconnaissances in the Cape Nome and Norton Bay regions, Alaska, in 1900: Special Publication B, pp. 70–154, 1901.

Burchard, E. F., A barite deposit near Wrangell: Bull. 592, pp. 109–117, 1914.

Capps, S. R., Mineral resources of the Bonnifield region: Bull. 480, pp. 218–235, pl. 10, 1911.

——— The Bonnifield region: Bull. 501, pp. 43–62, 1912.

——— Gold placers of the Yentna district: Bull. 520, pp. 174–200, pls. 8–9, 1912.

——— The Yentna district, Alaska: Bull. 533, pp. 64–136, 1913.

——— Gold lodes and placers of the Willow Creek district: Bull. 592, pp. 245–272, pl. 10, 1914.

——— Mineral resources of the Chisana-White River district: Bull. 622, pp. 189–228, pl. 9, 1915.

——— The Willow Creek district: Bull. 607, pp. 49–83, 1915.

CAPPS, S. R., The Chisana-White River district, Alaska: Bull. 630, pp. 89–126, 1916.
——— The Turnagain-Knik region: Bull. 642, pp. 181–194, pls. 6–8, 1916.
——— Gold mining in the Willow Creek district: Bull. 642, pp. 195–200, 1916.
——— Mineral resources of the Kantishna region: Bull. 662, pp. 279–331, pl. 15, 1917.
CAPPS, S. R., and JOHNSON, B. L., Mineral deposits of the Ellamar district: Bull. 542, pp. 96–124, pl. 4, 1913.
CHAPIN, THEODORE, The McKinley Lake district: Bull. 542, pp. 78–80, pl. 3, 1913.
——— Lode developments on Seward Peninsula: Bull. 592, pp. 397–407, pl. 17, 1914.
——— Lode mining near Fairbanks: Bull. 592, pp. 321–355, pl. 15, 1914.
——— Placer mining in the Yukon-Tanana region: Bull. 592, pp. 357–362, 1914.
——— Placer mining on Seward Peninsula: Bull. 592, pp. 385–395, 1914.
——— Auriferous gravels of the Nelchina-Susitna region: Bull. 622, pp. 125–130, pl. 6, 1915.
——— Mining developments in southeastern Alaska: Bull. 642, pp. 73–104, pls. 2–3, 1916.
——— Mining developments in the Ketchikan and Wrangell mining districts: Bull. 662, pp. 63–75, pl. 5, 1917.
——— The Nelchina-Susitna region, Alaska: Bull. 668, 67 pp., 10 pls., 1918.
COLLIER, A. J., The coal resources of the Yukon, Alaska: Bull. 218, pp. 19–67, 1903.
——— The Glenn Creek gold mining district, Alaska: Bull. 213, pp. 49–56, 1903.
——— Coal resources of the Yukon basin, Alaska: Bull. 213, pp. 276–283, 1903.
——— Tin deposits of the York region, Alaska: Bull. 225, pp. 154–167, 1903.
——— Tin deposits of the York region, Alaska: Bull. 229, 61 pp., 1904.
——— Auriferous quartz veins on Unalaska Island: Bull. 259, pp. 102–103, 1905.
——— Recent development of Alaskan tin deposits: Bull. 259, pp. 120–127, 1905.
——— Coal fields of the Cape Lisburne region: Bull. 259, pp. 172–185, 1905.
——— Geology and coal resources of the Cape Lisburne region, Alaska: Bull. 278, pp. 35–50, 1906.
COLLIER, A. J., and others, The gold placers of parts of Seward Peninsula, Alaska, including the Nome, Council, Kougarok, Port Clarence, and Goodhope precincts: Bull. 328, 343 pp., 1908.
DALL, W. H., Report on coal and lignite of Alaska: Seventeenth Ann. Rept., pt. 1, pp. 763–908, 1896.
EAKIN, H. M., The Rampart and Hot Springs regions: Bull. 520, pp. 271–286, pl. 13, 1912.
——— A geologic reconnaissance of a part of the Rampart quadrangle, Alaska: Bull. 535, pp. 28–38, 1913.
——— Gold placers of the Ruby and Innoko-Iditarod districts: Bull. 542, pp. 288–303, pl. 10, 1913.
——— The Iditarod-Ruby region, Alaska: Bull. 578, pp. 31–45, 1914.
——— Placer mining in the Ruby district: Bull. 592, pp. 363–369, 1914.
——— Mineral resources of the Yukon-Koyukuk region: Bull. 592, pp. 371–384, pl. 16, 1914.
——— Tin mining in Alaska: Bull. 622, pp. 81–94, pls. 2–3, 1915.
——— Mining in the Juneau region: Bull. 622, pp. 95–102, 1915.
——— Mining in the Fairbanks districts: Bull. 622, pp. 229–238, 1915.
——— Mining in the Hot Springs district: Bull. 622, pp. 239–245, 1915.
——— Iron-ore deposits near Nome: Bull. 622, pp. 361–365, 1915.
——— Placer mining in Seward Peninsula: Bull. 622, pp. 366–373, 1915.
——— Exploration in the Cosna-Nowitna region: Bull. 642, pp. 211–222, pl. 10, 1916.
——— Lode mining in the Juneau gold belt: Bull. 662, pp. 77–92, pls. 6–7, 1917.
——— Gold placer mining in the Porcupine district: Bull. 662, pp. 93–100, pl. 8, 1917.
——— The Cosna-Nowitna region, Alaska: Bull. 667, 54 pp., 8 pls., 1917.

ELDRIDGE, G. H., A reconnaissance in the Susitna basin and adjacent territory, Alaska, in 1898: Twentieth Ann. Rept., pt. 7, pp. 20–24, 1900.
ELLSWORTH, C. E., Placer mining in the Yukon-Tanana region: Bull. 442, pp. 230–245, 1909.
——— Placer mining in the Fairbanks and Circle districts: Bull. 520, pp. 240–245, 1912.
ELLSWORTH, C. E., and DAVENPORT, R. W., Placer mining in the Yukon-Tanana region: Bull. 542, pp. 203–222, 1913.
ELLSWORTH, C. E., and PARKER, G. L., Placer mining in the Yukon-Tanana region: Bull. 480, pp. 153–172, 1911.
GRANT, U. S., Copper and other mineral resources of Prince William Sound: Bull. 284, pp. 78–85, 1906.
GRANT, U. S., and HIGGINS, D. F., jr., Notes on the geology and mineral prospects in the vicinity of Seward, Kenai Peninsula: Bull. 379, pp. 98–107, 1909.
——— Copper mining and prospecting on Prince William Sound: Bull. 379, pp. 87–97, pl. 4, 1909.
——— Preliminary report on the mineral resources of the southern part of Kenai Peninsula: Bull. 442, pp. 166–178, pls. 3–4, 1910.
——— Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska: Bull. 443, pp. 52–79, 1910.
HARRINGTON, G. L., Gold placers of the Anvik-Andreafski region: Bull. 662, pp. 340–349, pl. 16, 1917.
HENSHAW, F. F., Mining in the Fairhaven precinct: Bull. 379, pp. 355–369, 1909.
——— Mining in Seward Peninsula: Bull. 442, pp. 353–371, 1909.
HESS, F. L., The York tin region: Bull. 284, pp. 145–157, 1906.
——— Tin resources of Alaska: Bull. 520, pp. 89–92, 1912.
JOHNSON, B. L., Gold deposits of the Seward-Sunrise region, Kenai Peninsula: Bull. 520, pp. 131–173, pl. 7, 1912.
——— The Port Wells gold-lode district: Bull. 592, pp. 195–236, pl. 9, 1914.
——— Mining on Prince William Sound: Bull. 592, pp. 237–243, 1914.
——— The Ellamar district, Alaska: Bull. 605, pp. 50–121, 1915.
——— Mining on Prince William Sound: Bull. 622, pp. 131–139, pl. 7, 1915.
——— The gold and copper deposits of the Port Valdez district: Bull. 622, pp. 140–188, pl. 8, 1915.
——— Mining on Prince William Sound: Bull. 642, pp. 137–145, 1916.
——— Mining on Prince William Sound: Bull. 662, pp. 183–192, pl. 12, 1917.
——— Copper deposits of the Latouche and Knight Island districts, Prince William Sound: Bull. 662, pp. 193–220, 1917.
KATZ, F. J., Gold placers of the Mulchatna: Bull. 442, pp. 201-202, 1910.
——— A reconnaissance of the Willow Creek gold region: Bull. 480, pp. 139–152, 1911.
KNOPF, ADOLPH, The Seward Peninsula tin deposits: Bull. 345, pp. 251–267, 1908.
——— The mineral deposits of the Lost River and Brooks Mountain region, Seward Peninsula: Bull. 345, pp. 268–271, 1908.
——— Geology of the Seward Peninsula tin deposits, Alaska: Bull. 358, pp. 24–67, 1908.
——— Geology of the Berners Bay region, Alaska: Bull. 446, pp. 29–48, 1910.
——— Mining in southeastern Alaska: Bull. 442, pp. 133–143, 1910.
——— Occurrence of iron ore near Haines: Bull. 442, pp. 144–146, 1910.
——— Mining in southeastern Alaska: Bull. 480, pp. 94–102, 1911.
——— The Eagle River region: Bull. 480, pp. 107–110, 1911.
——— The Eagle River region, southeastern Alaska: Bull. 502, pp. 34–60, 1912.
——— The Sitka mining district, Alaska: Bull. 504, pp. 21–32, 1912.
MADDREN, A. G., Gold placers of the Ruby Creek, Gold Hill, and Innoko districts: Bull. 379, pp. 229–266, pl. 9, 1909.

Maddren, A. G., The Koyukuk-Chandalar gold region: Bull. 442, pp. 284–315, pl. 7, 1909.

——— The Innoko gold-placer district, Alaska, with an account of the central Kuskokwim Valley and the Ruby Creek and Gold Hill placers: Bull. 410, pp. 61–83, 1910.

——— Gold-placer mining developments in the Innoko-Iditarod region: Bull. 480, pp. 236–270, pl. 11, 1911.

——— The Ruby placer district: Bull. 520, pp. 292–296, pl. 14, 1912.

——— The Koyukuk-Chandalar region, Alaska: Bull. 532, pp. 68–116, 1913.

——— Mineral deposits of the Yakataga district: Bull. 592, pp. 119–153, pl. 4, 1914.

——— Gold placers of the lower Kuskokwim, with a note on copper in the Russian Mountains: Bull. 622, pp. 298–360, pl. 11, 1915.

——— Gold placers near the Nenana coal field: Bull. 662, pp. 363–402, 1917.

Martin, G. C., Petroleum fields of Alaska and the Bering River coal fields: Bull. 225, pp. 365–382, 1903.

——— The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits: Bull 250, pp. 22–59, 1905.

——— The Cape Yaktag placers: Bull. 259, pp. 88–89, 1905.

——— Gold deposits of the Shumagin Islands: Bull. 259, pp. 100–101, 1905.

——— Notes on the petroleum fields of Alaska: Bull. 259, pp. 128–139, 1905.

——— Bering River coal field: Bull. 259, pp. 140–150, 1905.

——— Markets for Alaska coal: Bull. 284, pp. 18–29, 1906.

——— Distribution and character of the Bering River coal: Bull. 284, pp. 65–77, pl. 12, 1906.

——— Preliminary statement on the Matanuska coal field: Bull. 284, pp. 88–100, 1906.

——— A reconnaissance of the Matanuska coal field, Alaska: Bull. 289, pp. 18–32, 1906.

——— The Alaska coal fields: Bull. 314, pp. 40–46, pl. 2, 1907.

——— Petroleum at Controller Bay: Bull. 314, pp. 89–103, 1907.

——— Geology and mineral resources of the Controller Bay region, Alaska: Bull. 335, pp. 65–130, 1908.

——— Preliminary report on a detailed survey of part of the Matanuska coal fields: Bull. 480, pp. 128–138, pls. 8–9, 1911.

——— Mineral deposits of Kodiak and the neighboring islands: Bull. 542, pp. 131–136, pl. 5, 1913.

Martin, G. C., and Katz, F. J., Outline of the geology and mineral resources of the Iliamna and Clark lakes region: Bull. 442, pp. 179–200, pl. 5, 1910.

——— Geology and coal fields of the lower Matanuska Valley, Alaska: Bull. 500, pp. 75–95, 1912.

——— A geologic reconnaissance of the Iliamna region, Alaska: Bull. 485, pp. 113–130, 1912.

Martin, G. C., and Mertie, J. B., jr., Mineral resources of the upper Matanuska and Nelchina valleys: Bull. 592, pp. 273–282, pl. 11, 1914.

Martin, G. C., Johnson, B. L., and Grant, U. S., Geology and mineral resources of Kenai Peninsula, Alaska: Bull. 587, 243 pp., 38 pls., 1915.

Mendenhall, W. C., The Chistochina gold field, Alaska: Bull. 213, pp. 71–75, 1903.

——— Geology of the central Copper River region, Alaska: Prof. Paper 41, pp. 90–125, 1905.

Mendenhall, W. C., and Schrader, F. C., The mineral resources of the Mount Wrangell district, Alaska: Prof. Paper 15, pp. 16–68, 1903.

——— Copper deposits of the Mount Wrangell region, Alaska: Bull. 213, pp. 141–148, 1903.

Mertie, J. B., jr., The gold placers of the Tolovana district: Bull. 662, pp. 221–277, pls. 13–14, 1917.

MERTIE, J. B., jr., Lode mining in the Fairbanks district: Bull. 662, pp. 403–424, pl. 18, 1917.
——— Lode mining and prospecting on Seward Peninsula: Bull. 662, pp. 425–449, 1917.
——— Placer mining on Seward Peninsula: Bull. 662, pp. 451–458, 1917.
MERTIE, J. B., jr., and HARRINGTON, G. L., Mineral resources of the Ruby-Kuskokwim region: Bull. 642, pp. 237–266, pl. 11, 1916.
MOFFIT, F. H., The Kotzebue placer gold field of Seward Peninsula, Alaska: Bull. 225, pp. 74–80, 1904.
——— Gold placers of Turnagain Arm, Cook Inlet: Bull. 259, pp. 90–99, 1905.
——— Gold deposits of the Shumagin Islands: Bull. 259, pp. 100–101, 1905.
——— The Fairhaven gold placers, Seward Peninsula, Alaska: Bull. 247, pp. 47–67, 1905.
——— Mineral resources of Kenai Peninsula, Alaska: Gold fields of the Turnagain Arm region: Bull. 277, pp. 7–53, 1906.
——— Gold mining on Seward Peninsula: Bull. 284, pp. 132–144, pl. 14, 1906.
——— The Nome region: Bull. 314, pp. 126–145, 1907.
——— Notes on copper prospects of Prince William Sound: Bull. 345, pp. 176–178, 1908.
——— Mining in the Kotsina-Chitina, Chistochina, and Valdez Creek regions: Bull. 379, pp. 153–160, 1909.
——— Mining in the Chitina district: Bull. 442, pp. 158–163, 1910.
——— The upper Susitna and Chistochina districts: Bull. 480, pp. 112–127, pl. 7, 1911.
——— Headwater regions of Gulkana and Susitna rivers, Alaska, with accounts of the Valdez Creek and Chistochina placer districts: Bull. 498, pp. 53–80, 1912.
——— The Taral and Bremner River districts: Bull. 520, pp. 93–104, pl. 5, 1912.
——— The Chitina copper district: Bull. 520, pp. 105–107, 1912.
——— Geology of the Nome and Grand Central quadrangles, Alaska: Bull. 533, pp. 64–136, 1913.
——— Mining in Chitina Valley: Bull. 542, pp. 81–85, 1913.
——— Geology of the Hanagita-Bremner region, Alaska: Bull. 576, pp. 43–54, 1914.
——— Preliminary report on the Broad Pass region: Bull. 592, pp. 301–305, pl. 12, 1914.
——— Mining in the Valdez Creek placer district: Bull. 592, pp. 307–308, 1914.
——— Mineral deposits of the Kotsina-Kuskulana district, with notes on mining in Chitina Valley: Bull. 622, pp. 103–117, pls. 4–5, 1915.
——— Mineral resources of the upper Chitina Valley: Bull. 642, pp. 129–136, pl. 5, 1916.
——— Mining in the lower Copper River basin: Bull. 662, pp. 155–182, pls. 10–11, 1917.
——— The upper Chitina Valley, Alaska, with a description of the igneous rocks by R. M. Overbeck: Bull. 675, 82 pp., 13 pls., 1918.
MOFFIT, F. H., and CAPPS, S. R., Geology and mineral resources of the Nizina district, Alaska, copper and gold: Bull. 448, pp. 75–108, 1911.
MOFFIT, F. H., and KNOPF, ADOLPH, Mineral resources of the Nabesna-White River district, Alaska: Bull. 379, pp. 161–180, pl. 7; Bull. 417, pp. 51–62, 1910.
——— Mineral resources of the upper Chitina Valley: Bull. 642, pp. 134–136, 1916.
MOFFIT, F. H., and MADDREN, A. G., The mineral resources of the Kotsina and Chitina valleys, Copper River region: Bull. 345, pp. 127–175, pl. 3, 1908.
——— Mineral resources of the Kotsina-Chitina region: Bull. 374, pp. 42–100, 1909.
OVERBECK, R. M., Lode deposits near the Nenana coal fields: Bull. 662, pp. 351–362, 1917.
PAIGE, SIDNEY, The Herendeen Bay coal field: Bull. 284, pp. 101–108. 1906.
PAIGE, SIDNEY, and KNOPF, ADOLPH, Reconnaissance in the Matanuska and Talkeetna basins, with notes on the placers of the adjacent region: Bull. 314, pp. 104–125, 1907.

Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. 327, pp. 40–68, 1907.

Porter, E. A., Placer mining in the Fortymile, Eagle, and Seventymile River districts: Bull. 520, pp. 211–218, 1912.

Prindle, L. M., Gold placers of the Fairbanks district, Alaska: Bull. 225, pp. 64–73, 1904.

——— The gold placers of the Fortymile, Birch Creek, and Fairbanks regions, Alaska: Bull. 251, 89 pp., 16 pls., 1905.

——— Yukon placer fields: Bull. 284, pp. 109–127, pl. 13, 1906.

——— The Yukon-Tanana region, Alaska: Bull. 295, pp. 20–27, 1906.

——— The Bonnifield and Kantishna regions: Bull. 314, pp. 205–226, pl. 4, 1907.

——— Occurrence of gold in the Yukon-Tanana region: Bull. 345, pp. 179–186, pl. 4, 1907.

——— The Fortymile gold placer district: Bull. 345, pp. 187–199, 1907.

——— The Fairbanks and Rampart quadrangles, Yukon-Tanana region, Alaska: Bull. 337, pp. 29–98, 1908.

——— Sketch of the geology of the northeastern part of the Fairbanks quadrangle: Bull. 442, pp. 203–209, pl. 6, 1909.

——— Auriferous quartz veins in the Fairbanks district: Bull. 442, pp. 210–229, 1909.

——— A geologic reconnaissance of the Circle quadrangle, Alaska: Bull. 538, pp. 54–67, 1913.

Prindle, L. M., and Hess, F. L., Rampart placer region: Bull. 259, pp. 104–119, 1905.

Prindle, L. M., and Katz, F. J., The Fairbanks gold-placer region: Bull. 379, pp. 181–200, pl. 8, 1909.

——— A geologic reconnaissance of the Fairbanks quadrangle, Alaska: Bull. 525, pp. 77–153, 1913.

Prindle, L. M., and Mertie, J. B., jr., Gold placers between Woodchopper and Fourth of July creeks, upper Yukon River: Bull. 520, pp. 201–210, pl. 10, 1912.

Purington, C. W., Methods and costs of gravel and placer mining in Alaska: Bull. 259, pp. 32–46, 1905.

Schrader, F. C., A reconnaissance in northern Alaska across the Rocky Mountains, along Koyukuk, John, Anaktuvuk, and Colville rivers and the Arctic coast to Cape Lisburne, in 1901: Prof. Paper 20, pp. 98–114, 1904.

Schrader, F. C., and Brooks, A. H., Preliminary report on the Cape Nome gold region, Alaska: Special Publication A, pp. 16–34, 1900.

Schrader, F. C., and Spencer, A. C., The geology and mineral resources of a portion of the Copper River district, Alaska: Special Publication C, pp. 79–92, 1901.

Smith, P. S., Gold fields of the Solomon and Niukluk River basins: Bull. 314, pp. 146–156, 1907.

——— Geology and mineral resources of Iron Creek: Bull. 314, pp. 157–163, 1907.

——— Investigations of the mineral deposits of Seward Peninsula: Bull. 345, pp. 206–250, pl. 5, 1908.

——— Recent developments in southern Seward Peninsula: Bull. 379, pp. 267–301, 1909.

——— The Iron Creek region: Bull. 379, pp. 302–354, pl. 10, 1909.

——— Geology and mineral resources of the Solomon and Casadepaga quadrangles, Seward Peninsula: Bull. 433, pp. 137–217, 1910.

——— The Squirrel River placers: Bull. 480, pp. 306–319, pl. 13, 1911.

——— Notes on mining in Seward Peninsula: Bull. 520, pp. 339–344, 1912.

——— The Alatna-Noatak region: Bull. 520, pp. 332–338, pl. 15, 1912.

——— Lode mining near Fairbanks: Bull. 525, pp. 153–216, 1913.

——— Lode mining near Fairbanks: Bull. 542, pp. 137–202, pl. 6, 1913.

SMITH, P. S., The Noatak-Kobuk region, Alaska: Bull. 536, pp. 125–157, 1913.
——— Lode mining in the Ketchikan region: Bull. 592, pp. 75–94, 1914.
——— Mineral resources of the Lake Clark-Iditarod region: Bull. 622, pp. 252–271, pl. 10, 1915.
——— The Lake Clark-central Kuskokwim region, Alaska: Bull. 655, pp. 127–156, 1917.
SMITH, P. S., and EAKIN, H. M., Mineral resources of the Nulato-Council region: Bull. 442, pp. 316–352, pl. 8, 1910.
——— A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: Bull. 449, pp. 100–141, 1911.
——— The Shungnak region, Kobuk Valley: Bull. 480, pp. 271–305, pl. 12, 1911.
SMITH, P. S., and MADDREN, A. G., Quicksilver deposits of the Kuskokwim region: Bull. 622, pp. 274–291, 1915.
SPENCER, A. C., The Juneau gold belt, Alaska: Bull. 225, pp. 28–42, 1904.
——— The Treadwell ore deposits, Douglas Island: Bull. 259, pp. 69–87, 1905.
SPURR, J. E., Geology of the Yukon gold district: Eighteenth Ann. Rept., pt. 3, pp. 317–382, 1898.
——— A reconnaissance in southwestern Alaska in 1898: Twentieth Ann. Rept., pt. 7, pp. 259–264, 1900.
STONE, R. W., Coal resources of southwestern Alaska: Bull. 259, pp. 151–171, pls. 2–3, 1905.
——— Coal fields of the Kachemak Bay region: Bull. 277, pp. 53–73, 1906.
——— Reconnaissance from Circle to Fort Hamlin: Bull. 284, pp. 128–131, 1906.
TARR, R. S., The Yakutat Bay region: Bull. 284, pp. 61–64, 1906.
WRIGHT, C. W., The Porcupine placer district, Alaska: Bull. 236, pp. 19–31, 1904.
——— The Porcupine placer mining district, Alaska: Bull. 225, pp. 60–63, 1904.
——— Nonmetallic deposits of southeastern Alaska: Bull. 284, pp. 55–60, 1906.
——— A reconnaissance of Admiralty Island, Alaska: Bull. 287, pp. 147–154, 1906.
——— Lode mining in southeastern Alaska: Bull. 314, pp. 47–72, pl. 3, 1907.
——— Nonmetalliferous mineral resources of southeastern Alaska: Bull. 314, pp. 73–81, 1907.
——— Lode mining in southeastern Alaska: Bull. 345, pp. 78–97, pl. 2, 1908.
——— Building stones and materials of southeastern Alaska: Bull. 345, pp. 116, 124–125, 1908.
——— Mining in southeastern Alaska: Bull. 379, pp. 67–86, pls. 2–3, 1909.
——— The geology and ore deposits of Copper Mountain and Kasaan Peninsula: Prof. Paper 87, pp. 85–108, 1915.
WRIGHT, C. W., and PAIGE, SIDNEY, Copper deposits on Kasaan Peninsula, Prince of Wales Island: Bull. 345, pp. 98–115, 1908.
WRIGHT, F. E., and WRIGHT, C. W., Economic developments in southeastern Alaska: Bull. 259, pp. 47–68, 1905.
——— Lode mining in southeastern Alaska: Bull. 284, pp. 30–54, pl. 11, 1906.
——— The Ketchikan and Wrangell mining districts, Alaska: Bull. 347, pp. 77–191, 1908.

ASBESTOS.

BROOKS, A. H., Distribution of mineral resources in Alaska: Bull. 345, p. 25, 1908.
DILLER, J. S., Asbestos: Mineral Resources for 1906, pp. 1123–1127, 1907.
——— Asbestos: Mineral Resources for 1908, pt. 2, pp. 697–706, 1909.
——— Asbestos: Mineral Resources for 1909, pt. 2, pp. 721–723, 726–729, 1911.
——— The types, modes of occurrence, and important deposits of asbestos in the United States: Bull. 470, pp. 505–524, 1911.
——— Asbestos: Mineral Resources for 1912, pt. 2, pp. 987–994, 1913.
——— Asbestos: Mineral Resources for 1913, pt. 2, pp. 342–351, 1914.
——— Asbestos: Mineral Resources for 1914, pt. 2, pp. 96–101, 1915.

DILLER, J. S., Asbestos: Mineral Resources for 1915, pt. 2, pp. 14–16, 1916.
——— Asbestos: Mineral Resources for 1916, pt. 2, pp. 19–22, 1917.
——— Asbestos: Mineral Resources for 1917, pt. 2, pp. 197–202, 1918.
KEITH, ARTHUR, Geol. Atlas, Asheville [N. C.-Tenn.] folio (No. 116), p. 9, 1904.
KEMP, J. F., Notes on the occurrence of asbestos in Lamoille and Orleans counties, Vt.: Mineral Resources for 1900, pp. 862–866, 1901.
PARKER, E. W., Asbestos: Twenty-first Ann. Rept., pt. 6 (continued), pp. 561–564, 1901.
PRATT, J. H., Asbestos: Mineral Resources for 1904, pp. 1125–1140, 1905.
SMITH, G. O., Asbestos: Mineral Resources for 1905, pp. 1155–1156, 1906.

BARIUM AND STRONTIUM.

BURCHARD, E. F., Barytes: Mineral Resources for 1906, pp. 1109–1111, 1907.
——— Barytes: Mineral Resources for 1907, pt. 2, pp. 685–696, 1908.
——— Barytes and strontium; Mineral Resources for 1909, pt. 2, pp. 697–700, 1911.
——— A barite deposit near Wrangell, Alaska: Bull. 592, pp. 109–117, 1914.
HAYES, C. W., and PHALEN, W. C., A commercial occurrence of barite near Cartersville, Ga.: Bull. 340, pp. 458–462, 1907.
HILL, J. M., Barytes and strontium in 1912: Mineral Resources for 1912, pt. 2, pp. 955–960, 1913.
——— The production of barytes in 1913: Mineral Resources for 1913, pt. 2, pp. 168–172, 1914.
——— Barytes and strontium in 1915: Mineral Resources for 1915, pt. 2, pp. 161–189, 1916.
——— Barytes and barium products: Mineral Resources for 1916, pt. 2, pp. 246–254, 1917.
KEITH, ARTHUR, Geol. Atlas, Asheville [N. C.-Tenn.] folio (No. 116), p. 9, 1904.
KNOPF, ADOLPH, Strontianite deposits near Barstow, Calif.: Bull. 660, pp. 257–270, 1918.
PHALEN, W. C., Celestite deposits in California and Arizona: Bull. 540, pp. 521–533, 1914.
PRATT, J. H., Strontium ores: Mineral Resources for 1901, pp. 955–958, 1902.
——— Barytes: Mineral Resources for 1904, pp. 1095–1098, 1905.
——— Strontium: Mineral Resources for 1916, pt. 2, pp. 185–195, 1917.
SMITH, G. O., Our mineral reserves: Bull. 599, pp. 31–33, 42–45, 1914.
STOSE, G. W., Barite in southern Pennsylvania: Bull. 225, pp. 515–517, 1904.

BAUXITE AND ALUMINUM.

BURCHARD, E. F., Bauxite and aluminum: Mineral Resources for 1906, pp. 501–509, 1907.
BUTLER, B. S., and GALE, H. S., Alunite, a newly discovered deposit near Marysvale, Utah: Bull. 511, 64 pp., 1912.
EMMONS, W. H., The enrichment of sulphide ores: Bull. 529, pp. 69, 151–155, 1913.
——— The enrichment of ore deposits: Bull. 625, pp. 475–480, 1917.
HAYES, C. W., Bauxite: Mineral Resources for 1893, pp. 159–167, 1894.
——— Bauxite: Mineral Resources for 1894, pp. 547–597, 1895.
——— The Arkansas bauxite deposits: Twenty-first Ann. Rept., pt. 3, pp. 441–472, 1901.
——— Bauxite: Geol. Atlas, Rome [Ga.-Ala.] folio (No. 78), p. 6, 1902.
HILL, J. M., Bauxite and aluminum: Mineral Resources for 1916, pt. 1, pp. 161–170, 1917.
——— Bauxite and aluminum: Mineral Resources for 1917, pt. 1, pp. 3–9, 1918.
HUNT, A. E., Aluminum: Aluminum manufacture in Europe: Mineral Resources for 1895, pp. 245–251, 1896.

LARSEN, E. S., Alunite in the San Cristobal quadrangle, Colo.: Bull. 530, pp. 179-183, 1913.

LOUGHLIN, G. F., Recent alunite developments near Marysvale and Beaver, Utah: Bull. 620, pp. 237-270, 1916.

PACKARD, R. L., Aluminum and bauxite: Mineral Resources for 1891, pp. 147-163, 1892.

——— Aluminum: Mineral Resources for 1894, pp. 539-545, 1895.

PHALEN, W. C., Bauxite and aluminum in 1911: Mineral Resources for 1911, pt. 1, pp. 924-932, 1912.

——— Bauxite and aluminum in 1912: Mineral Resources for 1912, pt. 1, pp. 951-955, 1913.

——— Bauxite and aluminum in 1913: Mineral Resources for 1913, pt. 1, pp. 3-25, 1914.

——— Bauxite and aluminum: Mineral Resources for 1914, pt. 1, pp. 188-199, 205-207, 1915.

——— Bauxite and aluminum: Mineral Resources for 1915, pt. 1, pp. 163-173, 1916.

SCHRADER, F. C., Alunite at Bovard, Nev.: Bull. 540, pp. 351-356, 1914.

——— Alunite in granite porphyry near Patagonia, Ariz.: Bull. 540, pp. 347-350, 1914.

SMITH, G. O., Our mineral reserves: Bull. 599, pp. 26-27, 1914.

CHROMITE.

DAY, D. T., Chromium; history of the chromium industry: Mineral Resources for 1883-84, pp. 567-571, 1885.

DILLER, J. S., Chromic iron ore in 1912: Mineral Resources for 1912, pt. 1, pp. 1050-1054, 1913.

——— The production of chromic iron ore in 1913: Mineral Resources for 1913, pt. 1, pp. 32-38, 1914.

——— Chromic iron ore in North America: Mineral Resources for 1914, pt. 1, pp. 5-15, 1915.

——— Chromite: Mineral Resources for 1916, pt. 1, pp. 21-36, 1917.

——— Chromite: Mineral Resources for 1917, pt. 1, pp. 37-38, 41-43, 1918.

EMMONS, W. H., The enrichment of ore deposits: Bull. 625, pp. 422-423, 1917.

GARRISON, F. L., Chromium; alloys of iron and chromium: Mineral Resources for 1894, Sixteenth Ann. Rept., pt. 3, pp. 610-614, 1895.

GLENN, WILLIAM, Chromic iron and its occurrence in Canada: Mineral Resources for 1895, Seventeenth Ann. Rept., pt. 3, pp. 261-273, 1896.

HARDER, E. C., Chromic iron ore: Mineral Resources for 1908, pp. 751-770, 1909.

——— Some chromite deposits in western and central California: Bull. 430, pp. 167-183, pl. 1, 1910.

HESS, F. L., Nickel and cobalt; alloys of cobalt and chromium: Mineral Resources for 1910, pt. 1, pp. 755-757, 1911.

——— Stellite, a cobalt-chromium alloy: Mineral Resources for 1912, pt. 1, pp. 965-967, 1913.

CLAY AND CLAY PRODUCTS.

ADAMS, G. I., and HAWORTH, ERASMUS: Economic geology of the Iola quadrangle, Kans.: Bull. 238, pp. 69-74, 1904.

ALDEN, W. C., Fuller's earth and brick clays near Clinton, Mass.: Bull. 430, pp. 402-404, 1910.

ASHLEY, G. H., Notes on clays and shales in central Pennsylvania: Bull. 285, pp. 442-444, 1906.

ASHLEY, H. E., The colloid matter of clay and its measurement: Bull. 388, 65 pp., 1909.

BASCOM, FLORENCE, and others: Geol. Atlas, Philadelphia [Pa.-N. J.-Del.] folio (No. 162), p. 21, 1909.
——— Geol. Atlas, Trenton [N. J.-Pa.] folio (No. 167), pp. 22-23, 1909.
BASTIN, E. S., Clays of the Penobscot Bay region, Maine: Bull. 285, pp. 428-431, 1906.
BAUER, C. M., Clay in northeastern Montana: Bull. 540, pp. 369-372, pl. 8, 1914.
BAYLEY, W. S., KUMMEL, H. B., and SALISBURY, R. D.: Geol. Atlas, Raritan [N. J.] folio (No. 191), p. 31, 1914.
BRANNER, J. C., The clays of Arkansas: Bull. 351, 247 pp., 1908.
BUTTS, CHARLES, Economic geology of the Kittanning and Rural Valley quadrangles, Pa.: Bull. 279, pp. 162-171, 1906.
——— Clays of the Birmingham district, Ala.: Bull. 315, pp. 291-295, 1907.
CRIDER, A. F., Clays of western Kentucky and Tennessee: Bull. 285, pp. 417-427, pl. 13, 1906.
DARTON, N. H., Geology and water resources of the northern portion of the Black Hills and adjoining regions in South Dakota and Wyoming: Prof. Paper 65, p. 96, 1909.
——— Economic geology of Richmond, Va., and vicinity: Bull. 483, pp. 36-43, 1911.
DARTON, N. H., and others, Geol. Atlas, Passaic [N. J.-N. Y.] folio (No. 157), pp. 25-26, 1908.
DEUSSEN, ALEXANDER, Notes on some clays from Texas: Bull. 470, pp. 302-352, pls. 6-8, 1911.
ECKEL, E. C., Stoneware and brick clays of western Tennessee and northwestern Mississippi: Bull. 213, pp. 382-391, 1903.
——— Clays of Garland County, Ark.: Bull. 285, pp. 407-411, 1906.
EMMONS, S. F., CROSS, WHITMAN, and ELDRIDGE, G. H., Geology of the Denver Basin in Colorado: Mon. 27, pp. 387-392, 1896.
FENNEMAN, N. M., Clay resources of the St. Louis district, Mo.: Bull. 315, pp. 315-321, 1907.
——— Geology and mineral resources of the St. Louis quadrangle, Mo.-Ill.: Bull. 438, pp. 49-54, 1911.
FISHER, C. A., The bentonite deposits of Wyoming: Bull. 260, pp. 559-563, 1905.
——— Clays in the Kootenai formation near Belt, Mont.: Bull. 340, pp. 417-423, pl. 5, 1908.
FULLER, M. L., Clays of Cape Cod, Mass.: Bull. 285, pp. 432-441, 1906.
HANCE, J. H., Clay-working industries; notes on the occurrence of different varieties of clay: Mineral Resources for 1912, pt. 2, pp. 609-618, 1913.
——— Clay-working industries; notes on the occurrence and use of flint clay: Mineral Resources for 1913, pt. 2, pp. 639-648, 1914.
HILL, R. T., Clay materials of the United States: Mineral Resources for 1891, pp. 476-528, 1893; idem for 1892, pp. 712-738, 1893; idem for 1893, pp. 605-617, 1894.
KATZ, F. J., Clay in the Portland region, Me.: Bull. 530, pp. 202-206, 1913.
LANDES, HENRY, The clay deposits of Washington: Bull. 260, pp. 550-558, 1905.
LINES, E. F., Clays and shales of the Clarion quadrangle, Clarion County, Pa.: Bull. 315, pp. 335-343, 1907.
MATSON, G. C., Notes on the clays of Florida: Bull. 380, pp. 346-356, 1909.
——— Notes on the clays of Delaware: Bull. 530, pp. 185-201, 1913.
——— Louisiana clays: Bull. 660, pp. 147-158, pl. 5, 1918.
MUNN, M. J., Geol. Atlas, Sewickley [Pa.] folio (No. 176), pp. 15-16, 1911.
PHALEN, W. C., Clay resources of northwestern Kentucky: Bull. 285, pp. 412-416, 1916.
——— Economic geology of the Kenova quadrangle, Kentucky, Ohio, and West Virginia: Bull. 349, pp. 112-122, 1908.
PHALEN, W. C., and MARTIN, LAWRENCE, Clays and shales of southwestern Cambria County, Pa.: Bull. 315, pp. 344-354, 1907.
——— Mineral resources of Johnstown, Pa., and vicinity: Bull. 447, pp. 113-126, 1911.

RICHARDSON, G. B., Geol. Atlas, Indiana [Pa.] folio (No. 102), pp. 6-7, 1904.
——— Clay near Calhan, El Paso County, Colo.: Bull. 470, pp. 293-296, 1911.
RIES, HEINRICH, Technology of the clay industry: Sixteenth Ann. Rept., pt. 4, pp. 523-575, 1895.
——— The pottery industry of the United States: Seventeenth Ann. Rept., pt. 3, pp. 842-880, 1896.
——— The clay-working industry in 1896: Eighteenth Ann. Rept., pp. 1105-1168, 1896.
——— Kaolins and fire clays of Europe: Nineteenth Ann. Rept., pt. 6 (continued), pp. 377-486, 1898.
——— The clay-working industry in 1897: Nineteenth Ann. Rept., pt. 6 (continued), pp. 469-486, 1898.
——— Clays and clay products at the Paris Exposition: Twenty-first Ann. Rept., pt. 6, pp. 365-392, 1901.
——— The clays of the United States east of the Mississippi River: Prof. Paper 11, 298 pp., 9 pls., 1903.
SCHRADER, F. C., and HAWORTH, ERASMUS, Clay industries of the Independence quadrangle, Kans.: Bull. 260, pp. 546-549, 1905.
——— Economic geology of the Independence quadrangle, Kans.: Bull. 296, pp. 58-61, 1906.
SHALER, M. K., and GARDNER, J. H., Clay deposits of the western part of the Durango-Gallup coal field of Colorado and New Mexico: Bull. 315, pp. 296-302, 1907.
SHALER, N. S., WOODWORTH, J. B., and MARBUT, C. F., The glacial brick clays of Rhode Island and southeastern Massachusetts: Seventeenth Ann. Rept., pt. 1, pp. 957-1004, 1896.
SHAW, E. W., Clay resources of the Murphysboro quadrangle, Ill.: Bull. 470, pp. 297-301, 1911.
SHAW, E. W., and SAVAGE, T. E., Geol. Atlas, Murphysboro-Herrin [Ill.] folio (No. 185), p. 15, 1913.
SIEBENTHAL, C. E., Bentonite of the Laramie Basin, Wyo.: Bull. 285, pp. 445-447, 1906.
SPROULL, H. S., Clay industries: Mineral Resources for 1885, pp. 414-423, 1886.
STOSE, G. W., White clays of South Mountain, Pa.: Bull. 315, pp. 322-334, 1907.
UDDEN, J. A., Geology and mineral resources of the Peoria quadrangle, Ill.: Bull. 506, pp. 89-90, 1912.
VEATCH, OTTO, Kaolins and fire clays of central Georgia: Bull. 315, pp. 303-314, 1907.
WILBER, F. A., Clays: Mineral resources for 1883-84, pp. 676-694, 1885.
WOOLSEY, L. H., Clays of the Ohio Valley in Pennsylvania: Bull. 225, pp. 463-480, 1904.
——— Economic geology of the Beaver quadrangle, Pa.: Bull. 286, pp. 55-71, 1906.
——— Geol. Atlas, Beaver [Pa.] folio (No. 134), pp. 12-13, 1905.

COAL.

ARNOLD, RALPH, Coal in Clallam County, Wash.: Bull. 260, pp. 413-421, 1905.
——— Coal in the Mount Diablo Range, Monterey County, Calif.: Bull. 285, pp. 223-225, 1906.
ASHBURNER, C. A., Anthracite: Mineral Resources for 1882, pp. 7-32, 1883.
ASHLEY, G. H., The eastern interior coal field: Twenty-second Ann. Rept., pt. 3, pp. 265-305, 1902.
——— Geol. Atlas, Ditney [Ind.] folio (No. 84), p. 7, 1902.
——— The Cumberland Gap coal field of Kentucky and Tennessee: Bull. 225, pp. 259-275, 1904.
——— Coal in the Nicholas quadrangle, W. Va.: Bull, 260, pp. 422-428, 1905.
——— Clearfield coal field, Pa.: Bull. 285, pp. 271-275, 1906.
——— Stratigraphy and coal beds of the Indiana coal field: Bull. 381, pp. 9-18, 1910.

ASHLEY, G. H., Rhode Island anthracite: Bull. 541, pp. 155-162, pl. 8, 1914.
——— Rhode Island coal: Bull. 615, 62 pp., 1915.
——— The Santo Tomas cannel coal, Webb County, Tex.: Bull. 691, pp. 251-270, pls. 29-32, 1918.
ASHLEY, G. H., and GLENN, L. C., Geology and mineral resources of the Cumberland Gap coal field, Ky.: Prof. Paper 49, 239 pp., 1906.
ATWOOD, W. W., Mineral resources of southwestern Alaska: Bull. 379, pp. 116-145 1909.
——— Geology and mineral resources of parts of the Alaska Peninsula: Bull. 467, pp. 96-120, 1911.
BAIN, H. F., The western interior coal field: Twenty-second Ann. Rept., pt. 3, pp. 333-366, 1902.
BALL, M. W., The western part of the Little Snake River coal field, Wyo.: Bull. 341, pp. 243-255, pl. 13, 1909.
BALL, M. W., and STEBINGER, EUGENE, The eastern part of the Little Snake River coal field: Bull. 381, pp. 186-213, pl. 13, 1910.
BARNETT, V. H., Geology of the Hound Creek district of the Great Falls coal field, Cascade County, Mont.: Bull. 641, pp. 215-231, pl. 22, 1917.
BAUER, C. M., Lignite in the vicinity of Plentywood and Scobey, Sheridan County, Mont.: Bull. 541, pp. 293-315, pls. 14-17, 1914.
BEEKLY, A. L., The Culbertson lignite field, Valley County, Mont.: Bull. 471, pp. 319-358, pls. 25-27, 1912.
——— Geology and coal resources of North Park, Colo.: Bull. 596, 121 pp., 12 pls., 1915.
BOWEN, C. F., The Baker lignite field, Custer County, Mont.: Bull. 471, pp. 202-226, pls. 14-15, 1912.
——— Coal at Horseshoe Bend and Jerusalem Valley, Boise County, Idaho: Bull. 531, pp. 245-251, pl. 15, 1913.
——— Lignite in the Goose Creek district, Cassia County, Idaho: Bull. 531, pp. 252-262, pl. 16, 1913.
——— Coal discovered in a reconnaissance survey between Musselshell and Judith, Mont.: Bull. 541, pp. 329-337, pl. 19, 1914.
——— The Cleveland coal field, Blaine County, Mont.: Bull. 541, pp. 338-355, pl. 20, 1914.
——— The Big Sandy coal field, Chouteau County, Mont.: Bull. 541, pp. 356-378, pl. 21, 1914.
BOWNOCKER, J. A., The coal fields of Ohio: Prof. Paper 100, pp. 35-96, 1917.
BROOKS, A. H., The coal resources of Alaska: Twenty-second Ann. Rept., pt. 3, pp. 515-571, 1902.
——— The Circle precinct [Alaska]: Bull. 314, pp. 201-204, 1907.
——— Alaska coal and its utilization: Bull. 442, pp. 47-100, 1910.
——— The Mount McKinley region, Alaska: Prof. Paper 70, pp. 184-193, 1911.
——— The Alaska mining industry in 1913: Bull. 592, pp. 43-74, 1914.
BROOKS, A. H., and MARTIN, G. C., Mineral resources of Alaska: Coal and peat: Bull. 394, pp. 174-188, 1909.
BURCHARD, E. F., Lignites of the middle and upper Missouri Valley: Bull. 225, pp. 276-288, 1904.
BURCHARD, E. F., and BUTTS, C., Iron ores, fuels, and fluxes of the Birmingham district, Ala.: Bull. 400, pp. 170-183, 1910.
BURROWS, J. S., The Barnesboro-Patton coal field of central Pennsylvania: Bull. 225, pp. 295-310, 1904.
BUTTS, CHARLES, The Warrior coal basin in the Brookwood quadrangle, Ala.: Bull. 260, pp. 357-381, 1905.
——— The Warrior coal basin in the Birmingham quadrangle, Ala.: Bull. 285, pp. 211-222, 1906.

BUTTS, CHARLES, Geol. Atlas, Kittanning [Pa.] folio (No. 115), pp. 12–13, 1904.
——— Geol. Atlas, Rural Valley [Pa.] folio (No. 125), pp. 7–10, 1905.
——— Geol. Atlas, Ebensburg [Pa.] folio (No. 133), pp. 7–9, 1905.
——— Economic geology of the Kittanning and Rural Valley quadrangles, Pa.: Bull. 279, pp. 44–102, 1906.
——— The northern part of the Cahaba coal field, Ala.: Bull. 316, pp. 76–115, pls. 5–6, 1907.
——— Geol. Atlas, Birmingham [Ala.] folio (No. 175), pp. 14–20, 1910.
——— The southern part of the Cahaba coal field, Ala.: Bull. 431, pp. 89–146, pl. 4, 1911.
——— The coal resources and general geology of the Pound quadrangle of Virginia and Kentucky: Bull. 541, pp. 165–221, pls. 9–11, 1914.
——— Coals in the area between Bon Air and Clifty, Tenn.: Bull. 641, pp. 307–310, 1917.
CALVERT, W. R., The Lewistown coal field, Mont.: Bull. 341, pp. 108–122, pl. 7, 1909.
——— Geology of the Lewistown coal field, Mont.: Bull. 390, 83 pp., 1909.
——— Geology of certain lignite fields in eastern Montana: Bull. 471, pp. 187–201, 1912.
——— The Livingston and Trail Creek coal fields, Park, Gallatin, and Sweetgrass counties, Mont.: Bull. 471, pp. 384–405, pl. 29, 1912.
——— The Electric coal field, Park County, Mont.: Bull. 471, pp. 406–422, pl. 30, 1912.
——— Geology of the upper Stillwater Basin, Stillwater and Carbon counties, Mont.: Bull. 641, pp. 199–214, pls. 20–21, 1917.
CAMPBELL, M. R., Geology of the Big Stone coal field of Virginia and Kentucky: Bull. 111, 106 pp., 1893.
——— Geol. Atlas, Estillville [Va.-Ky.-Tenn.] folio (No. 12), pp. 4–5, 1894.
——— Geol. Atlas, Pocahontas [Va.-W. Va.] folio (No. 26), pp. 4–5, 1896.
——— Geol. Atlas, Tazewell [Va.-W. Va.] folio (No. 44), pp. 4–5, 1897.
——— Geol. Atlas, London [Ky.] folio (No. 47), p. 3, 1898.
——— Geol. Atlas, Standingstone [Tenn.] folio (No. 53), pp. 3–4, 1899.
——— Geol. Atlas, Bristol [Va.-Tenn.] folio (No. 59), pp. 6–8, 1899.
——— Geol. Atlas, Huntington [W. Va.-Ohio] folio (No. 69), pp. 5–6, 1900.
——— Geol. Atlas, Danville [Ill.-Ind.] folio (No. 67), pp. 6–7, 1900.
——— Geol. Atlas, Charlestown [W. Va.] folio (No. 72), pp. 6–9, 1901.
——— Geol. Atlas, Raleigh [W. Va.] folio (No. 77), pp. 4–8, 1902.
——— Geol. Atlas, Masontown-Uniontown [Pa.] folio (No. 82), pp. 10–18, 1902.
——— Geol. Atlas, Brownsville-Connellsville [Pa.] folio (No. 94), pp. 11–17, 1903.
——— Recent work in the bituminous coal field of Pennsylvania: Bull. 213, pp. 270–275, 1903.
——— The Meadow Branch coal field of West Virginia: Bull. 225, pp. 330–344, 1904.
——— The Deer Creek coal field, Ariz.: Bull. 225, pp. 248–258, 1904.
——— Survey work on coal during 1905: Bull. 285, pp. 203–210, 1906.
——— Coal of Stone Canyon, Monterey County, Calif.: Bull. 316, pp. 435–438, 1907.
——— The Una del Gato coal field, Sandoval County, N. Mex.: Bull. 316, pp. 427–430, 1907.
——— Coal in the vicinity of Fort Stanton Reservation, Lincoln County, N. Mex.: Bull. 316, pp. 431–434, 1907.
——— Map showing coal fields of the United States: Mineral Resources for 1907, 1908.
——— Coal fields of North Dakota and Montana; introduction: Bull. 341, pp. 5–14, pl. 1, 1909.
——— Coal in San Benito County, Calif.: Bull. 431, pp. 243–247, 1911.
CAMPBELL, M. R., CLAPP, F. G., and BUTTS, CHARLES, Geol. Atlas, Barnesboro-Patton [Pa.] folio (No. 189), pp. 10–11, 1913.

CAMPBELL, M. R., and GREGORY, H. E., The Black Mesa coal field, Ariz.: Bull. 431, pp. 229-238, pl. 11, 1911.

CAMPBELL, M. R., and PARKER, E. W., Coal fields of the United States: Bull. 394, pp. 7-26, pl. 1, 1909.

CAMPBELL, M. R., and WOODRUFF, E. G., The Powell Mountain coal field, Scott and Wise counties, Va.: Bull. 431, pp. 147-162, pl. 5, 1911.

CAPPS, S. R., Mineral resources of the Bonnifield region [Alaska]: Bull. 480, pp. 231-235, 1911.

——— The Bonnifield region, Alaska: Bull. 501, pp. 54-62, 1912.

CLAPP, F. G., Economic geology of the Amity quadrangle, eastern Washington County, Pa.: Bull. 300, pp. 88-117, 1907.

——— Geol. Atlas, Amity [Pa.] folio (No. 144), pp. 12-13, 1907.

CLARK, F. R., Coal near Thompson, Grand County, Utah: Bull. 541, pp. 453-477, pl. 28, 1914.

——— Coal near Wales, Sanpete County, Utah: Bull. 541, pp. 478-489, pl. 29, 1914.

——— Geology of the Lost Creek coal field, Morgan County, Utah: Bull. 691, pp. 311-322, pl. 40, 1918.

COLLIER, A. J., Coal resources of the Yukon basin, Alaska: Bull. 213, pp. 276-283, 1903.

——— The coal resources of the Yukon, Alaska: Bull. 218, 71 pp., 1903.

——— Coal fields of the Cape Lisburne region [Alaska]: Bull. 259, pp. 172-185, 1905.

——— Geology and coal resources of the Cape Lisburne region, Alaska: Bull. 278, 54 pp., 1906.

——— The Arkansas coal field: Bull. 316, pp. 137-160, pl. 9, 1907.

——— The Arkansas coal field, with reports on the paleontology by David White and G. H. Girty: Bull. 326, 158 pp., 1907.

——— Coal resources of Cowlitz River valley, Cowlitz and Lewis counties, Wash.: Bull. 531, pp. 323-330, pl. 24, 1913.

——— Coal south of Mancos, Montezuma County, Colo.: Bull. 691, pp. 293-310, pls. 34-39, 1918.

COLLIER, A. J., and SMITH, C. D., The Miles City coal field, Mont.: Bull. 341, pp. 36-61, pl. 3, 1909.

DALL, W. H., Report on coal and lignite of Alaska: Seventeenth Ann. Rept., pt, 1, pp. 772-834, 1896.

DARTON, N. H., Geol. Atlas, Newcastle [Wyo.-S. Dak.] folio (No. 107), pp. 8-9, 1904.

——— Preliminary report on the geology and underground water resources of the central Great Plains: Prof. Paper 32, pp. 372-379, 1905.

——— Geol. Atlas, Sundance [Wyo.-S. Dak.] folio (No. 127), p. 12, 1905.

——— Mineral resources of the Bighorn Mountain region [Wyo.]: Bull. 285, pp. 303-310, 1906.

——— Geology of the Bighorn Mountains [Wyo.] Prof. Paper 51, pp. 62-67, 1906.

——— Geol. Atlas, Bald Mountain-Dayton [Wyo.] folio (No. 141), p. 14, 1906.

——— Geol. Atlas, Cloud Peak-Fort McKinney [Wyo.] folio (No. 142), p. 15, 1906.

——— Coals of Carbon County, Mont.: Bull. 316, pp. 174-193, pl. 11, 1907.

DARTON, N. H., and SIEBENTHAL, C. E., Geology and mineral resources of the Laramie Basin, Wyo.: Bull. 364, pp. 53-56, 1909.

DARTON, N. H., and TAFF, J. A., Geol. Atlas, Piedmont [Md.-W. Va.] folio (No. 28), p. 5, 1896.

DAVIS, J. A., The Little Powder River coal field, Campbell County, Wyo.: Bull. 471, pp. 423-440, pls. 31-34, 1912.

DEWOLF, F. W., Coal investigation in the Saline-Gallatin field, Ill., and the adjoining area: Bull. 316, pp. 116-136, pls. 7-8, 1907.

DILLER, J. S., A geologic reconnaissance in northwestern Oregon: Seventeenth Ann. Rept., pt. 1, pp. 491-508, 1896.

DILLER, J. S., The Coos Bay coal field, Oreg.: Nineteenth Ann. Rept., pt. 3, pp. 309–376, 1899.
——— Geol. Atlas, Coos Bay [Oreg.] folio (No. 73), pp. 4–5, 1901.
——— Geol. Atlas, Port Orford [Oreg.] folio (No. 89), pp. 4–5, 1903.
——— Coal in Washington near Portland, Oreg.: Bull. 260, pp. 411–412, 1905.
——— The Rogue River Valley coal field, Oreg.: Bull. 341, pp. 401–405, 1909.
——— Mineral resources of southwestern Oregon: Bull. 546, pp. 130–140, 1914.
DILLER, J. S., and PISHEL, M. A., Preliminary report on the Coos Bay coal field, Oreg.: Bull. 431, pp. 190–228, pls. 7–10, 1911.
ELDRIDGE, G. H., Geol. Atlas, Anthracite-Crested Butte [Colo.] folio (No. 9), pp. 9–10, 1894.
——— Geology of the Denver Basin in Colorado: Mon. 27, pp. 317–387, 1896.
FENNEMAN, N. M., and GALE, H. S., The Yampa coal field, Routt County, Colo.: Bull. 285, pp. 226–239, pl. 6, 1906.
FINLAY, G. I., Geol. Atlas, Colorado Springs [Colo.] folio (No. 203), p. 14, 1916.
FISHER, C. A., Coal of the Big Horn Basin in northwest Wyoming: Bull. 225, pp. 345–364, 1904.
——— Coal fields of the White Mountain region, New Mexico: Bull. 225, pp. 293–294, 1904.
——— Mineral resources of the Big Horn Basin [Wyo.]: Bull. 285, pp. 311–315, 1906.
——— Geology and water resources of the Big Horn Basin, Wyo.: Prof. Paper 53, pp. 46–56, 1906.
——— Development of the Bear Creek coal field, Mont.: Bull. 285, pp. 269–270, 1906.
——— The Great Falls coal field, Mont.: Bull. 316, pp. 161–173, pl. 10, 1907.
——— Geology of the Great Falls coal field, Mont.: Bull. 356, 85 pp., 1909.
——— The Pocket coal district, Va., in the Little Black Mountain coal field: Bull. 341, pp. 409–418, 1909.
FULLER, M. L., and ASHLEY, G. H., Recent work in the coal field of Indiana and Illinois: Bull. 213, pp. 284–293, 1903.
GALE, H. S., Coal fields of the Danforth Hills and Grand Hogback in northwestern Colorado: Bull. 316, pp. 264–301, pls. 15–17, 1907.
——— Coal fields of northwestern Colorado and northeastern Utah: Bull. 341, pp. 283–315, pls. 16–20, 1909.
——— Coal fields of northwestern Colorado and northeastern Utah: Bull. 415, 265 pp., 22 pls., 1910.
GALE, H. S., and WEGEMANN, C. H., The Buffalo coal field, Wyo.: Bull. 381, pp. 137–169, pls. 9–11, 1910.
GARDNER, J. H., The coal field between Gallina and Raton Spring, N. Mex., in the San Juan coal region: Bull. 341, pp. 335–351, pl. 22, 1909.
——— The coal field between Durango, Colo., and Monero, N. Mex.: Bull. 341, pp. 352–363, pl. 23, 1909.
——— The coal field between Gallup and San Mateo, N. Mex.: Bull. 341, pp. 364–378, pl. 24, 1909.
——— Isolated coal fields in Santa Fe and San Miguel counties, N. Mex.: Bull. 381, pp. 447–451, 1910.
——— The coal field between San Mateo and Cuba, N. Mex.: Bull. 381, pp. 461–473, pl. 22, 1910.
——— The Carthage coal field, N. Mex.: Bull. 381, pp. 452–460, pl. 21, 1910.
GOLDMAN, M. I., The Colorado Springs coal field, Colo.: Bull. 381, pp. 317–340, pl. 17, 1910.
GREENE, F. C., The coal resources of a part of northeastern Missouri: Bull. 541, pp. 223–242, pl. 12, 1914.
GREGORY, H. E., Geology of the Navajo country—a reconnaissance of parts of Arizona, New Mexico, and Utah: Prof. Paper 93, pp. 143–145, 1917.

GRISWOLD, W. T., Pittsburg coal in the Burgettstown quadrangle, Pa.: Bull. 260, pp. 402-410, pl. 3, 1905.

HANCE, J. H., The Glendive lignite field, Dawson County, Mont.: Bull. 471, pp. 271-283, pls. 19-20, 1912.

——— The Coaldale coal field, Esmeralda County, Nev.: Bull. 531, pp. 313-322, pl. 23, 1912.

HARRINGTÓN, G. L., Gold placers of the Anvik-Andreafski region [Alaska]: Bull. 662, pp. 346-347, 1917.

HAYES, C. W., Geol. Atlas, Ringgold [Ga.-Tenn.] folio (No. 2), p. 2, 1894.

——— Geol. Atlas, Kingston [Tenn.] folio (No. 4), p. 3, 1894.

——— Geol. Atlas, Chattanooga [Tenn.] folio (No. 6), p. 3, 1894.

——— Geol. Atlas, Sewanee [Tenn.] folio (No. 8), p. 3, 1894.

——— Geol. Atlas, Stevenson [Ga.-Ala.-Tenn.] folio (No. 19), p. 3, 1895.

——— Geol. Atlas, Pikeville [Tenn.] folio (No. 21), p. 3, 1895.

——— Geol. Atlas, McMinnville [Tenn.] folio (No. 22), pp. 2-3, 1895.

——— Geol. Atlas, Gadsden [Ala.] folio (No. 35), p. 3, 1896.

——— The coal fields of the United States: Twenty-second Ann. Rept., pt. 3, pp. 7-24, 1902.

——— The southern Appalachian coal field: Twenty-second Ann. Rept., pt. 3, pp. 227-263, 1902.

HAZELTINE, R. M., The bituminous coal field of Ohio: Twenty-second Ann. Rept., pt. 3, pp. 215-226, 1902.

HERALD, F. A., The Terry lignite field, Custer County, Mont.: Bull. 471, pp. 227-270, pls. 16-18, 1912.

——— The Williston lignite field, Williams County, N. Dak.: Bull. 531, pp. 91-157, pls. 9-10, 1913.

HILLS, R. C., Coal fields of Colorado: Mineral Resources for 1892, pp. 319-361, 1893.

——— Geol. Atlas, Elmore [Colo.] folio (No. 58), pp. 3-4, 1899.

——— Geol. Atlas, Walsenburg [Colo.] folio (No. 68), pp. 4-5, 1900.

——— Geol. Atlas, Spanish Peaks [Colo.] folio (No. 71), pp. 4-6, 1901.

HINDS, HENRY, and GREENE, F. C., Geol. Atlas, Leavenworth-Smithville [Mo.-Kans.] folio (No. 206), pp. 10-12, 1917.

IDDINGS, J. P., and WEED, W. H., Geol. Atlas, Livingston [Mont.] folio (No. 1), pp. 3-4, 1894.

KEITH, ARTHUR, Geol. Atlas, Loudon [Tenn.] folio (No. 25), p. 5, 1896.

——— Geol. Atlas, Briceville [Tenn.] folio (No. 33), p. 4, 1896.

——— Geol. Atlas, Wartburg [Tenn.] folio (No. 40), p. 3, 1897.

KEYES, C. R., Sketch of the coal deposits of Iowa: Mineral Resources for 1892, pp. 398-404, 1893.

KNIGHT, W. C., Coals and coal measures of Wyoming: Sixteenth Ann. Rept., pt. 4, pp. 208-215, 1895.

LANE, A. C., The northern interior coal field: Twenty-second Ann. Rept., pt. 3, pp. 307-331, 1902.

LEE, W. T., The Engle coal field, N. Mex.: Bull. 285, p. 240, 1906.

——— The Iron County coal field, Utah: Bull. 316, pp. 359-374, pl. 21, 1907.

——— The Grand Mesa coal field, Colo.: Bull. 341, pp. 316-334, pl. 21, 1909.

——— Coal fields of Grand Mesa and the West Elk Mountains, Colo.: Bull. 510, 237 pp., 21 pls., 1912.

——— The Tijeras coal field, Bernalillo County, N. Mex.: Bull. 471, pp. 575-578, pl. 59, 1912.

——— The Cerrillos coal field, Santa Fe County, N. Mex.: Bull. 531, pp. 285-312, pls. 20-22, 1913.

LEE, W. T., and KNOWLTON, F. H., Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico: Prof. Paper 101, pp. 162-180, 1918.

LEONARD, A. G., The North Dakota-Montana lignite area: Bull. 285, pp. 316–330, 1906.

——— The coal fields of parts of Dawson, Rosebud, and Custer counties, Mont.: Bull. 316, pp. 194–211, pl. 12, 1907.

——— Geol. Atlas, Bismarck [N. Dak.] folio (No. 181), pp. 6–7, 1912.

LEONARD, A. G., and SMITH, C. D., The Sentinel Butte lignite field, N. Dak.-Mont.: Bull. 341, pp. 15–35, pl. 2, 1909.

LESHER, C. E., The Eden Ridge coal field, Coos County, Oreg.: Bull. 541, pp. 399–418, pls. 24–25, 1914.

LINES, E. F., Coals of the Clarion quadrangle, Clarion County, Pa.: Bull. 316, pp. 13–19, pl. 1, 1907.

LLOYD, E. R., The Cannonball River lignite field, N. Dak.: Bull. 541, pp. 243–291, pl. 13, 1914.

LUPTON, C. T., The eastern part of the Bull Mountain coal field, Mont.: Bull. 431, pp. 163–189, pls. 6–7, 1911.

——— The Deep Creek district of the Vernal coal field, Uinta County, Utah: Bull. 471, pp. 579–594, pl. 60, 1912.

——— The Blacktail (Tabby) Mountain coal field, Wasatch County, Utah: Bull. 471, pp. 595–628, pls. 61–62, 1912.

——— The Orofino coal field, Clearwater, Lewis, and Idaho counties, Idaho: Bull. 621, pp. 99–108, 1916.

——— Geology and coal resources of Castle Valley, in Carbon, Emery, and Sevier counties, Utah: Bull. 628, 88 pp., 12 pls., 1916.

MCCREATH, A. S., and D'INVILLIERS, E. V., The Clinch Valley coal fields [Va.]: Mineral Resources for 1892, pp. 521–528, 1893.

MARTIN, G. C., Petroleum fields of Alaska and the Bering River coal fields: Bull. 225, pp. 371–375, 1904.

——— The petroleum fields of the Pacific coast of Alaska, with an account of the Bering River coal deposits: Bull. 250, pp. 27–36, 1905.

——— Bering River coal field [Alaska]: Bull. 259, pp. 140–150, 1905.

——— Markets for Alaska coal: Bull. 284, pp. 18–29, 1906.

——— Distribution and character of the Bering River [Alaska] coal: Bull. 284, pp. 65–77, 1906.

——— Preliminary statement on the Matanuska coal field [Alaska]: Bull. 284, pp. 88–100, 1906.

——— A reconnaissance of the Matanuska coal field, Alaska: Bull. 289, 36 pp., 1906.

——— The Alaska coal fields: Bull. 314, pp. 40–46, 1907.

——— Geology and mineral resources of the Controller Bay region, Alaska: Bull. 335, pp. 65–112, 1908.

——— Geol. Atlas, Accident-Grantsville [Md.-Pa.-W. Va.] folio (No. 160), pp. 11–13, 1908.

——— Coal of the Denver Basin, Colo.: Bull. 381, pp. 297–306, 1910.

——— Preliminary report on a detailed survey of part of the Matanuska coal fields [Alaska]: Bull. 480, pp. 128–138, 1911.

MARTIN, G. C., and KATZ, F. J., Geology and coal fields of the lower Matanuska Valley, Alaska: Bull. 500, 95 pp., 1912.

MARTIN, G. C., JOHNSON, B. L., and GRANT, U. S., Geology and mineral resources of Kenai Peninsula, Alaska: Bull. 587, 243 pp., 38 pls., 1915.

MARTIN, G. C., and MERTIE, J. B., jr., Mineral resources of the upper Matanuska and Nelchina valleys [Alaska]: Bull. 592, pp. 282–298, 1914.

MENDENHALL, W. C., A coal prospect on Willow Creek, Morrow County, Oreg.: Bull. 341, pp. 406–408, 1909.

MUNN, M. J., Geol. Atlas, Sewickley [Pa.] folio (No. 176), pp. 14–15, 1911.

——— Geol. Atlas, Claysville [Pa.] folio (No. 180), pp. 12–13, 1912.

Paige, Sidney, The Herendeen Bay coal field [Alaska]: Bull. 284, pp. 101–108, 1906.
Paige, Sidney, and Knopf, Adolph, Geologic reconnaissance in the Matanuska and Talkeetna basins, Alaska: Bull. 327, pp. 40–63, 1907.
——— Reconnaissance in the Matanuska and Talkeetna basins [Alaska], with notes on the placers of the adjacent region: Bull. 314, pp. 109–115, 1907.
Pardee, J. T., Coal in the Tertiary lake beds of southwestern Montana: Bull. 531, pp. 229–244, pl. 14, 1913.
Parker, E. W., Coal: Mineral Resources for 1910, pp. 98–225, pls. 1–14, 1911.
Peck, F. B., and Ashley, G. H., The Punxsutawney and Glen Campbell coal fields of Indiana and Jefferson counties, Pa.: Bull. 285, pp. 276–279, 1906.
Pepperberg, L. J., The Milk River coal field, Mont.: Bull. 381, pp. 82–107, pl. 6, 1910.
——— The southern extension of the Milk River coal field, Chouteau County, Mont.: Bull. 471, pp. 359–383, pl. 28, 1912.
Phalen, W. C., Coal resources of the Kenova quadrangle [Ky.-W. Va.-Ohio]: Bull. 285, pp. 259–268, 1906.
——— Coal resources of Johnstown, Pa., and vicinity: Bull. 316, pp. 20–41, pl. 2, 1907.
——— Economic geology of the Kenova quadrangle in Kentucky, Ohio, and West Virginia: Bull. 349, pp. 25–112, 1908.
——— Geol. Atlas, Johnstown [Pa.] folio (No. 174), pp. 10–12, 1910.
——— Geol. Atlas, Kenova [Ky.-W. Va.-Ohio] folio (No. 184), pp. 8–14, 1912.
Phalen, W. C., and Martin, Lawrence, Mineral resources of Johnstown, Pa., and vicinity: Bull. 477, pp. 35–113, 1911.
Pishel, M. A., Lignite in the Fort Berthold Indian Reservation, N. Dak., north of Missouri River: Bull. 471, pp. 170–186, pls. 12–13, 1912.
Prindle, L. M., The Bonnifield and Kantishna regions [Alaska]: Bull. 314, pp. 221–226, 1907.
Richards, R. W., The central part of the Bull Mountain coal field, Mont.: Bull. 381, pp. 60–81, pls. 4–5, 1910.
Richardson, G. B., Coal in Sanpete County, Utah: Bull. 285, pp. 280–284, pl. 8, 1906.
——— The Book Cliffs coal field between Grand River, Colo., and Sunnyside, Utah: Bull. 316, pp. 302–320, pl. 18, 1907.
——— The Harmony, Colob, and Kanab coal fields, southern Utah: Bull. 341, pp. 379–400, pl. 25, 1909.
——— Reconnaissance of the Book Cliffs coal field between Grand River, Colo., and Sunnyside, Utah: Bull. 371, 54 pp., 1909.
——— The Trinidad coal field, Colo.: Bull. 381, pp. 379–446, pls. 19–20, 1910.
Rogers, G. S., The Little Sheep Mountain coal field, Dawson, Custer, and Rosebud counties, Mont.: Bull. 531, pp. 159–227, pls. 11–13, 1913.
——— Geology and coal resources of the area southwest of Custer, Yellowstone, and Big Horn counties, Mont.: Bull. 541, pp. 316–328, pl. 18, 1914.
Schrader, F. C., A reconnaissance in northern Alaska: Prof. Paper 20, pp. 106–114, 1904.
——— The Durango-Gallup coal field of Colorado and New Mexico: Bull. 285, pp. 241–258, pl. 7, 1906.
Schrader, F. C., and Haworth, Erasmus, Economic geology of the Independence quadrangle, Kans.: Bull. 296, pp. 48–52, 1906.
Schultz, A. R., Coal fields in a portion of central Uinta County, Wyo.: Bull. 316, pp. 212–241, pl. 13, 1907.
——— The northern part of the Rock Springs coal field, Sweetwater County, Wyo.: Bull. 341, pp. 256–282, pls. 14–15, 1909.

SCHULTZ, A. R., The southern part of the Rock Springs coal field, Sweetwater County, Wyo.: Bull. 381, pp. 214–281, pls. 14–15, 1910.
——— Weathering of coal in the arid region of the Green River basin, Sweetwater County, Wyo.: Bull. 381, pp. 282–296, 1910.
——— A geologic reconnaissance for phosphate and coal in southeastern Idaho and western Wyoming: Bull. 680, pp. 64–79, 1918.
——— Geology and geography of a portion of Lincoln County, Wyo.: Bull. 543, pp. 90–115, 1914.
SHALER, M. K., A reconnaissance survey of the western part of the Durango-Gallup coal field of Colorado and New Mexico: Bull. 316, pp. 375–426, pls. 22–23, 1907.
SHALER, N. S., Geology of the Naragansett Basin [R. I.]: Mon. 33, pp. 79–88, 1899.
SHALER, N. S., and WOODWORTH, J. B., Geology of the Richmond Basin, Va.: Nineteenth Ann. Rept., pt. 2, pp. 511–515, 1899.
SHAW, E. W., The Glenrock coal field, Wyo.: Bull. 341, pp. 151–164, pl. 9, 1909.
SHAW, E. W., LINES, E. F., and MUNN, M. J., Geol. Atlas, Foxburg-Clarion [Va.] folio (No. 178), pp. 13–14, 1911.
SHAW, E. W., and MUNN, M. J., Geol. Atlas, Burgettstown-Carnegie [Pa.] folio (No. 177), pp. 10–11, 1911.
——— Coal, oil, and gas of the Foxburg quadrangle, Pa.: Bull. 454, pp. 40–66, 1911.
SHAW, E. W., and SAVAGE, T. E., Geol. Atlas, Murphysboro-Herrin [Ill.] folio (No. 185), pp. 13–15, 1913.
——— Geol. Atlas, Tallula-Springfield [Ill.] folio (No. 188), pp. 11–12, 1913.
SIEBENTHAL, C. E., Coal of the Laramie Basin, Wyo.: Bull. 316, pp. 261–263, 1907.
——— Mineral resources of northeastern Oklahoma: Bull. 340, pp. 213–217, 1908.
SMITH, C. D., The Washburn lignite field, N. Dak.: Bull. 381, pp. 19–29, pl. 1, 1910.
——— The Fort Berthold Indian Reservation lignite field, N. Dak.: Bull. 381, pp. 30–39, pl. 2, 1910.
——— The Fort Peck Indian Reservation lignite field: Bull. 381, pp. 40–59, pl. 3, 1910.
SMITH, E. A., The coal measures of Alabama: Mineral Resources for 1892, pp. 293–299, 1893.
SMITH, E. E., The eastern part of the Great Divide Basin coal field, Wyo.: Bull. 341, pp. 220–242, pl. 12, 1909.
——— Coals of the State of Washington: Bull. 474, 206 pp., 8 pls., 1911.
SMITH, G. O., The coal fields of the Pacific coast: Twenty-second Ann. Rept., pt. 3, pp. 473–513, 1902.
——— Geol. Atlas, Mount Stuart [Wash.] folio (No. 106), pp. 9–10, 1904.
——— Our mineral reserves: Bull. 599, pp. 11–12, 1914.
SMITH, G. O., and CALKINS, F. C., Geol. Atlas, Snoqualmie [Wash.] folio (No. 139), p. 13, 1906.
SMITH, P. S., The Noatak-Kobuk region, Alaska: Bull. 536, pp. 151–153, 1913.
SMITH, P. S., and EAKIN, H. M., A geologic reconnaissance in southeastern Seward Peninsula and the Norton Bay-Nulato region, Alaska: Bull. 449, pp. 136–140, 1911.
SMITH, W. S. T., and SIEBENTHAL, C. E., Geol. Atlas, Joplin district [Mo.-Kans.] folio (No. 148), pp. 19–20, 1907.
SPURR, J. E., Coal deposits between Silver Peak and Candelaria, Esmeralda County, Nev.: Bull. 225, pp. 289–292, 1904.
——— Ore deposits of the Silver Peak quadrangle, Nev.: Prof. Paper 55, pp. 165–168, 1906.
STEBINGER, EUGENE, The Sidney lignite field, Dawson County, Mont.: Bull. 471, pp. 284–318, pls. 21–24, 1912.
——— Geology and coal resources of northern Teton County, Mont.: Bull. 621, pp. 117–156, pls. 15–16, 1916.
STOEK, H. H., The Pennsylvania anthracite coal field: Twenty-second Ann. Rept., pt. 3, pp. 55–117, 1902.

Stone, R. W., The Elders Ridge coal field, Pa.: Bull. 225, pp. 311–324, 1904.
——— Mineral resources of the Elders Ridge quadrangle, Pa.: Bull. 256, pp. 31–54, 1905.
——— Geol. Atlas, Waynesburg [Pa.] folio (No. 121), pp. 9–10, 1905.
——— Geol. Atlas, Elders Ridge [Pa.] folio (No. 123), pp. 7–9, 1905.
——— Coal resources of southwestern Alaska: Bull. 259, pp. 151–171, 1905.
——— Mineral resources of the Kenai Peninsula: Coal fields of the Kachemak Bay region [Alaska]: Bull. 277, pp. 53–73, 1906.
——— The Elkhorn coal field, Ky.: Bull. 316, pp. 42–54, pl. 3, 1907.
——— The Russell Fork coal field, Va.: Bull. 316, pp. 55–67, pl. 4, 1907.
——— Coal resources of the Russell Fork basin in Kentucky and Virginia: Bull. 348, 127 pp., 1908.
——— Coal near the Crazy Mountains, Mont.: Bull. 341, pp. 78–91, pl. 5, 1909.
——— Coal on Dan River, N. C.: Bull. 471, pp. 137–169, pl. 11, 1912.
——— Coal near the Black Hills, Wyo.-S. Dak.: Bull. 499, 66 pp., 7 pls., 1912.
Stone, R. W., and Lupton, C. T., The Powder River coal field, Wyo.: Bull. 381, pp. 115–136, pl. 8, 1910.
Storrs, L. S., The Rocky Mountain coal fields: Twenty-second Ann. Rept., pt. 3, pp. 415–471, 1902.
Taff, J. A., Geology of the McAlester-Lehigh coal field, Ind. T.: Nineteenth Ann. Rept., pt. 3, pp. 423–456, 1899.
——— Preliminary report on the Camden coal field of southwestern Arkansas: Twenty-first Ann. Rept., pt. 2, pp. 319–329, 1900.
——— Geol. Atlas, Coalgate [Okla.] folio (No. 74), p. 6, 1901.
——— The southwestern coal field: Twenty-second Ann. Rept., pt. 3, pp. 367–413, 1902.
——— Geol. Atlas, Atoka [Okla.] folio (No. 79), p. 7, 1902.
——— Progress of coal work in Indian Territory: Bull. 260, pp. 382–401, pls. 1–2, 1905.
——— Geol. Atlas, Muscogee [Okla.] folio (No. 132), p. 6, 1906.
——— Notes on the Weber River coal field, Utah: Bull. 285, pp. 285–288, 1906.
——— Book Cliffs coal field, Utah, west of Green River: Bull. 285, pp. 289–302, pl. 9, 1906.
——— The Pleasant Valley coal district, Carbon and Emery counties, Utah: Bull. 316, pp. 338–358, pl. 20, 1907.
——— The Durango coal district, Colo.: Bull. 316, pp. 321–337, pl. 19, 1907.
——— The Sheridan coal field, Wyo.: Bull. 341, pp. 123–150, pl. 8, 1909.
Taff, J. A., and Adams, G. I., Geology of the eastern Choctaw coal field, Indian Territory: Twenty-first Ann. Rept., pt. 2, pp. 257–311, 1900.
Taff, J. A., and Brooks, A. H., Geol. Atlas, Buckhannon [W. Va.] folio (No. 34), p. 3, 1896.
Udden, J. A., Geology and mineral resources of the Peoria quadrangle, Ill.: Bull. 506, pp. 80–88, 1912.
Udden, J. A., and Shaw, E. W., Geol. Atlas, Belleville-Breese [Ill.] folio (No. 195), pp. 10–12, 1915.
Vaughan, T. W., Reconnaissance in the Rio Grande coal fields of Texas: Bull. 164, 100 pp., 1900.
Veatch, A. C., Coal and oil in southern Uinta County, Wyo.: Bull. 285, pp. 331–353, pls. 10–12, 1906.
——— Coal fields of east-central Carbon County, Wyo.: Bull. 316, pp. 244–260, pl. 14, 1907.
——— Geography and geology of a portion of southwestern Wyoming: Prof. Paper 56, 178 pp., 1908.
——— Coal deposits near Pinedale, Navajo County, Ariz.: Bull. 431, pp. 239–242, pl. 12, 1911.

127972°—19——16

WASHBURNE, C. W., Coal fields of the northeast side of the Big Horn Basin, Wyo., and of Bridger, Mont.: Bull. 341, pp. 165-199, pl. 10, 1909.
——— The South Park coal field, Colo.: Bull. 381, pp. 307-316, pl. 16, 1910.
——— The Canon City coal field, Colo.: Bull. 381, pp. 341-378, pl. 18, 1910.
WEED, W. H., Geol. Atlas, Fort Benton [Mont.] folio (No. 55), pp. 6-7, 1899.
——— Geol. Atlas, Little Belt Mountains [Mont.] folio (No. 56), p. 7, 1899.
WEEKS, J. D., The Potomac and Roaring Creek coal fields in West Virginia: Fourteenth Ann. Rept., pt. 2, pp. 567-590, 1894.
WEGEMANN, C. H., Notes on the coals of the Custer National Forest, Mont.: Bull. 381, pp. 108-114, pl. 7, 1910.
——— The Sussex coal field, Johnson, Natrona, and Converse counties, Wyo.: Bull. 471, pp. 441-471, pls. 35-43, 1912.
——— The Barber coal field, Johnson County, Wyo.: Bull. 531, pp. 263-284, pls. 17-19, 1913.
——— Geology and coal resources of the Sierra Blanca coal field, Lincoln and Otero counties, N. Mex.: Bull. 541, pp. 419-452, pls. 26-27, 1914.
——— The Coalville coal field, Utah: Bull. 581, pp. 161-184, pls. 6-11, 1915.
WHITE, DAVID, The bituminous coal field of Maryland: Twenty-second Ann. Rept., pt. 3, pp. 201-214, 1902.
WHITE, DAVID, and CAMPBELL, M. R., The bituminous coal field of Pennsylvania: Twenty-second Ann. Rept., pt. 3, pp. 127-200, 1902.
WHITE, DAVID, CAMPBELL, M. R., and HAZELTINE, R. M., The northern Appalachian coal field: Twenty-second Ann. Rept., pt. 3, pp. 119-226, 1902.
WHITE, I. C., Stratigraphy of the bituminous coal field in Pennsylvania, Ohio, and West Virginia: Bull. 65, 205 pp., 1891.
WILDER, F. A., The lignite of North Dakota and its relation to irrigation: Water-Supply Paper 117, 59 pp., 1905.
WILLIS, BAILEY, The lignites of the Great Sioux Reservation; a report on the region between the Grand and Moreau rivers, Dak.: Bull. 21, 16 pp., 1885.
——— Some coal fields of Puget Sound [Wash.]: Eighteenth Ann. Rept., pt. 3, pp. 393-436, 1898.
WILLIS, BAILEY, and SMITH, G. O., Geol. Atlas, Tacoma [Wash.] folio (No. 54), pp. 7-9, 1899.
WINCHESTER, D. E., The Lost Spring coal field, Converse County, Wyo.: Bull. 471, pp. 471-515, pls. 44-48, 1912.
WINCHESTER, D. E., HARES, C. J., LLOYD, E. R., and PARKS, E. M., The lignite field of northwestern South Dakota: Bull. 627, 169 pp., 11 pls., 1916.
WINSLOW, ARTHUR, The coal measures of Missouri: Mineral Resources for 1892, pp. 429-436, 1893.
WOODRUFF, E. G., The Red Lodge coal field [Mont.]: Bull. 341, pp. 92-107, pl. 6, 1909.
——— Coal fields of the southwest side of the Big Horn Basin, Wyo.: Bull. 341, pp. 200-219, 1909.
——— The coal fields in the southeastern part of the Big Horn Basin, Wyo.: Bull. 381, pp. 170-185, pl. 12, 1910.
——— The coal resources of Gunnison Valley, Mesa and Delta counties, Colo.: Bull. 471, pp. 565-573, pl. 58, 1912.
——— The Horseshoe Creek district of the Teton Basin coal field, Fremont County, Idaho: Bull. 541, pp. 379-388, pl. 22, 1914.
——— The Glacier coal field, Whatcom County, Wash.: Bull. 541, pp. 389-398, pl. 23, 1914.
WOODRUFF, E. G., and WINCHESTER, D. E., Coal fields of the Wind River region, Fremont and Natrona counties, Wyo.: Bull. 471, pp. 516-564, pls. 49-57, 1912.
WOODWORTH, J. B., The Atlantic coast Triassic coal field: Twenty-second Ann. Rept., pt. 3, pp. 25-53, 1901.

Woolsey, L. H., Economic geology of the Beaver quadrangle, Pa.: Bull. 286, pp. 26–55, 1906.

——— The Bull Mountain coal field, Mont.: Bull. 341, pp. 62–77, pl. 4, 1909.

Woolsey, L. H., Richards, R. W., and Lupton, C. T., The Bull Mountain coal field, Musselshell and Yellowstone counties, Mont.: Bull. 647, 218 pp., 36 pls., 1917.

Wright, C. W., A reconnaissance of Admiralty Island [Alaska]: Bull. 287, pp. 151–154, 1906.

Note.—Technologic reports on coal-testing, data, and field work incidental to coal are found in Professional Paper 48 and in Bulletins 9, 27, 42, 55, 60, 64, 78, 90, 261, 285, 290, 316, 323, 325, 332, 333, 334, 336, 339, 343, 362, 363, 366, 373, 378, 382, 383, 385, 394, 402, 403, 412, 416, 424, 425, 428, 471, 531, 541, 621.

COPPER.

Bain, H. F., and Ulrich, E. O., The copper deposits of Missouri: Bull. 260, pp. 233–235, 1905.

——— The copper deposits of Missouri: Bull. 267, 52 pp., 1905.

Ball, S. H., Copper deposits of the Hartville uplift, Wyo.: Bull. 315, pp. 93–107, 1907.

Bancroft, Howland, Reconnaissance of the ore deposits in northern Yuma County Ariz.: Bull. 451, pp. 40–93, 1911.

——— The ore deposits of northeastern Washington: Bull. 550, pp. 27–29, 174–210, passim, 1914.

Bastin, E. S., and Hill, J. M., Economic geology of Gilpin County and adjacent parts of Clear Creek and Boulder counties, Colo.: Prof. Paper 94, pp. 126–129, 150–151, 177–367 passim, 1917.

——— Preliminary report on the economic geology of Gilpin County, Colo.: Bull. 620, pp. 295–323, 1916.

Boutwell, J. M., Ore deposits of Bingham, Utah: Bull. 213, pp. 105–122, 1903.

——— Ore deposits of Bingham, Utah: Bull. 260, pp. 236–241, 1905.

——— Economic geology of the Bingham mining district, Utah: Prof. Paper 38, pp. 103–194 passim, 1905.

Brooks, A. H., Geologic features of Alaskan metalliferous lodes: Bull. 480, pp. 43–93, 1911.

Butler, B. S., Geology and ore deposits of the San Francisco and adjacent districts, Utah: Prof. Paper 80, pp. 92–172, 1913.

——— Notes on the Unaweep copper district, Colo.: Bull. 580, pp. 19–23, 1914.

——— Copper: Mineral Resources for 1916, pt. 1, pp. 626–631, 1918.

Butler, B. S., and Heikes, V. C., Notes on the Promontory district, Utah: Bull. 640, pp. 1–10, 1917.

Capps, S. R., The Chisana-White River district [Alaska]: Bull. 630, pp. 89–90, 119–125, 1916.

Capps, S. R., and Johnson, B. L., Mineral deposits of the Ellamar district [Alaska]: Bull. 542, pp. 86–124, 1913.

Collier, A. J., Ore deposits in the St. Joe River basin, Idaho: Bull. 285, pp. 129–139, pl. 4, 1906.

Diller, J. S., Copper deposits of the Redding region, Calif.: Bull. 213, pp. 123–132. 1903.

——— Mining and mineral resources in the Redding district [Calif.] in 1903: Bull, 225, pp. 169–179, 1904.

——— Mineral resources of southwestern Oregon: Bull. 546, pp. 72–88, 1914.

——— Geol. Atlas, Redding [Calif.] folio (No. 138), pp. 11–12, 1906.

Emmons, S. F., Copper in the red beds of the Colorado Plateau region [Ariz.]: Bull. 260, pp. 221–232, 1905.

——— The Cactus copper mine, Utah: Bull. 260, pp. 242–248, 1905.

EMMONS, S. F., and TOWER, G. W., Geol. Atlas, Butte special [Mont.] folio (No. 38), pp. 3–8, 1897.
EMMONS, W. H., The Cashin mine, Montrose County, Colo.: Bull. 285, pp. 125–128, 1906.
——— Some ore deposits of Maine and the Milan mine, N. H.: Bull. 432, pp. 15–47, 1910.
——— The enrichment of sulphide ores: Bull. 529, pp. 98–113, 162–165, 1913.
EMMONS, W. H., and LANEY, F. B., Preliminary report on the mineral deposits of Ducktown, Tenn.: Bull. 470, pp. 151–172, 1911.
GALE, H. S., Geology of the copper deposits near Montpelier, Bear Lake County, Idaho: Bull. 430, pp. 112–121, 1910.
GRANT, U. S., Copper and other mineral resources of Prince William Sound: Bull. 284, pp. 78–87, 1906,
GRANT, U. S., and HIGGINS, D. F., jr., Copper mining and prospecting on Prince William Sound [Alaska]: Bull. 379, pp. 87–96, 1909.
——— Reconnaissance of the geology and mineral resources of Prince William Sound, Alaska: Bull. 443, pp. 52–70, 1910.
GRATON, L. C., The occurrence of copper in Shasta County, Calif.: Bull. 430, pp. 71–111, 1910.
GREGORY, H. E., Geology of the Navajo country—a reconnaissance of parts of Arizona, New Mexico, and Utah: Prof. Paper 93, pp. 140–142, 1917.
HILL, J. M., Copper deposits of the White Mesa district, Ariz.: Bull. 540, pp. 159–163, 1914.
——— The Grand Gulch mining region, Mohave County, Ariz.: Bull. 580, pp. 39–58, 1905.
IRVING, J. D., and BANCROFT, H., Geology and ore deposits near Lake City, Colo.: Bull. 478, pp. 52–64, 1911.
IRVING, R. D., The copper-bearing rocks of Lake Superior: Mon. 5, 464 pp., 1883.
——— The copper-bearing rocks of Lake Superior: Third Ann. Rept., pp. 89–188, 1883.
JOHNSON, B. L., The gold and copper deposits of the Port Valdez district [Alaska]: Bull. 622, pp. 140–188, 1915.
——— Copper deposits of the Latouche and Knight Island districts, Prince William Sound [Alaska]: Bull. 662, pp. 193–220, 1917.
JONES, E. L., jr., A reconnaissance in the Kofa Mountains, Ariz.: Bull. 620, pp. 163–164, 1916.
KIRCHHOFF, CHARLES, Copper: Twenty-first Ann. Rept., pt. 6, pp. 177–188, 1901.
KNOPF, ADOLPH, Geology and ore deposits of the Yerington district, Nev.: Prof. Paper 114, pp. 31–66, 1918.
LAFORGE, LAURENCE, and PHALEN, W. C., Geol. Atlas, Ellijay [Ga.–N. C.–Tenn.] folio (No. 187), p. 13, 1913.
LINDGREN, WALDEMAR, The copper deposits of the Seven Devils [Idaho]: Twentieth Ann. Rept., pt. 3, pp. 249–253, 1900.
——— Copper deposits [in eastern Oregon]: Twenty-second Ann. Rept., pt. 2, pp. 629–634, 1901.
——— Copper deposits at Clifton, Ariz.: Bull. 213, pp. 133–140, 1903.
——— Copper deposits of Bisbee, Ariz.: Bull. 213, pp. 149–157, 1903.
——— Geol. Atlas, Clifton [Ariz.] folio (No. 129), pp. 11–13, 1905.
——— The copper deposits of the Clifton-Morenci district, Ariz.: Prof. Paper 43, 375 pp., 1905.
——— Notes on copper deposits in Chaffee, Fremont, and Jefferson counties, Colo.: Bull. 340, pp. 157–174, 1908.
——— Resources of the United States in gold, silver, copper, lead, and zinc: Bull. 394, pp. 133–143, pl. 9, 1909.
——— The mining districts of the western United States: Bull. 507, pp. 5–43 passim, 1912.

LINDGREN, WALDEMAR, GRATON, L. C., and GORDON, C. H., The ore deposits of New Mexico: Prof. Paper 68, pp. 17–78, 1910.

LINDGREN, WALDEMAR, and LOUGHLIN, G. F., Geology and ore deposits of the Tintic mining district, Utah: Prof. Paper 107, pp. 139–140, 144–147, 163–165, 1919.

LOUGHLIN, G. F., A reconnaissance in the Canyon Range, west-central Utah: Prof. Paper 90, pp. 51–60, 1905.

——— Zinc carbonate and related copper carbonate ores at Ophir, Utah: Bull. 690, pp. 1–14, 1918.

MADDREN, A. G., Gold placers of the lower Kuskokwim, with a note on copper in the Russian Mountains [Alaska]: Bull. 622, pp. 358–360, 1915.

MENDENHALL, W. C., Geology of the central Copper River region, Alaska: Prof. Paper 41, pp. 91–107, 1905.

MENDENHALL, W. C., and SCHRADER, F. C., Copper deposits of the Mount Wrangell region, Alaska: Bull. 213, pp. 141–148, 1903.

——— The mineral resources of the Mount Wrangell district, Alaska: Prof. Paper 15, pp. 13–41, 1903.

MOFFIT, F. H., Notes on copper prospects of Prince William Sound [Alaska]: Bull. 345, pp. 176–178, 1908.

——— Mining in the Kotsina-Chitina, Chistochina, and Valdez Creek regions [Alaska]: Bull. 379, pp. 153–160, 1909.

——— Mining in the Chitina district [Alaska]: Bull. 442, pp. 159–165, 1910.

——— The Chitina copper district [Alaska]: Bull. 520, pp. 105–107, 1912.

——— Mining in Chitina Valley [Alaska]: Bull. 542, pp. 81–85, 1913.

——— Geology of the Hanagita-Bremner region, Alaska: Bull. 576, pp. 51–53, 1914.

——— Mining in the lower Copper River basin: Bull. 662, pp. 155–182, 1917.

MOFFIT, F. H., and CAPPS, S. R., Geology and mineral resources of the Nizina district, Alaska, copper and gold: Bull. 448, pp. 77–97, 1911.

MOFFIT, F. H., and MADDREN, A. G., Mineral resources of the Kotsina-Chitina region, Alaska: Bull. 374, pp. 44–92, 1909.

NOBLE, L. F., The Shinumo quadrangle, Grand Canyon district, Ariz.: Bull. 549, pp. 93–96, 1914.

PAIGE, SIDNEY, Metalliferous ore deposits near the Burro Mountains, Grant County, N. Mex.: Bull. 470, pp. 131–150, pl. 4, 1911.

——— Geol. Atlas, Silver City [N. Mex.] folio (No. 199), pp. 14–17, 1916.

PHALEN, W. C., Copper deposits near Luray, Va.: Bull. 285, pp. 140–143, 1906.

——— Copper deposits of Bisbee, Ariz.: Bull. 213, pp. 149–157, 1903.

RANSOME, F. L., The Globe copper district, Ariz.: Prof. Paper 12, pp. 117–129, 1904.

——— Geology and ore deposits of the Bisbee quadrangle, Ariz.: Prof. Paper 21, pp. 109–123, 1904.

——— Geol. Atlas, Globe [Ariz.] folio (No. 111), pp. 14–16, 1904.

——— Geol. Atlas, Bisbee [Ariz.] folio (No. 112), pp. 13–15, 1904.

——— The Yerington copper district, Nev.: Bull. 380, pp. 99–119, 1909.

——— The Turquoise copper-mining district, Ariz.: Bull. 530, pp. 125–134, 1913.

——— Copper deposits near Superior, Ariz.: Bull. 540, pp. 139–158, 1914.

RANSOME, F. L., and CALKINS, F. C., The geology and ore deposits of the Coeur d'Alene district, Idaho: Prof. Paper 62, pp. 83–95, 150–153, 1908.

RICHARDS, R. W., Notes on lead and copper deposits in the Bear River Range, Idaho and Utah: Bull. 470, pp. 177–187, 1911.

SCHRADER, F. C., A reconnaissance of the Jarbidge, Contact, and Elk Mountain mining districts, Elko County, Nev.: Bull. 497, pp. 112–113, 1912.

——— Mineral deposits of the Santa Rita and Patagonia mountains, Ariz.: Bull. 582, pp. 27–30, 284, 318–320, 1915.

SMITH, G. O., Our mineral reserves: Bull. 599, pp. 25–26, 1914.

SPENCER, A. C., Mineral resources of the Encampment copper region, Wyo.: Bull. 213, pp. 158–162, 1903.

——— Reconnaissance examination of the copper deposits at Pearl, Colo.: Bull. 213, pp. 163–169, 1903.

——— Copper deposits of the Encampment district, Wyo.: Prof. Paper 25, 107 pp., 1904.

——— Geology and ore deposits of Ely, Nev.: Prof. Paper 96, pp. 100–127 passim, 1917.

STOSE, G. W., The copper deposits of South Mountain, in southern Pennsylvania: Bull. 430, pp. 122–131, 1910.

TOWER, G. W., jr., and SMITH, G. O., Geology and mining industry of the Tintic district, Utah: Nineteenth Ann. Rept., pp. 601–767, 1898.

——— Geol. Atlas, Tintic special [Utah] folio (No. 65), pp. 6–7, 1900.

TURNER, H. W., Geol. Atlas, Jackson [Calif.] folio (No. 11), p. 6, 1894.

UMPLEBY, J. B., A preliminary account of the ore deposits of the Loon Creek district, Idaho: Bull. 530, pp. 66–74, 1911.

——— Geology and ore deposits of Lemhi County, Idaho: Bull. 528, pp. 13–76 passim, 1913.

——— Some ore deposits in northwestern Custer County, Idaho: Bull. 539, pp. 35–97, 1913.

——— Geology and ore deposits of the Mackay region, Idaho: Prof. Paper 97 pp. 83–94, 1917.

VAN HISE, C. R., and LEITH, C. K., The geology of the Lake Superior region: Mon. 52, pp. 573–592, 1911.

WATSON, T. L., Notes on the Seminole copper deposits of Georgia: Bull. 225, pp. 182-186, 1904.

WEED, W. H., Ore deposits at Butte, Mont.: Bull. 213, pp. 170–180, 1903.

——— Copper deposits of the Appalachian States: Bull. 213, pp. 181–185, 1903.

——— Copper deposits in Georgia: Bull. 225, pp. 180–181, 1903.

——— The Griggstown, N. J., copper deposit: Bull. 225, pp. 187–189, 1903.

——— Notes on the copper mines of Vermont: Bull. 225, pp. 190–199, 1903.

——— The copper mines of the United States in 1905: Bull. 285, pp. 93–124, pl. 3, 1906.

——— Copper deposits of the Appalachian States: Bull. 455, 166 pp., 1911.

——— Geology and ore deposits of the Butte district, Mont.: Prof. Paper 74, pp. 67–70, 113–239, 1912.

WEED, W. H., EMMONS, S. F., and TOWER, G. W., Geol. Atlas, Butte special [Mont.] folio (No. 38), pp. 4–7, 1896.

WEED, W. H., and PIRSSON, L. V., Geology of the Castle Mountain mining district, Mont.: Bull. 139, pp. 156–157, 1896.

WEEKS, F. B., and HEIKES, V. C., Notes on the Fort Hall mining district, Idaho: Bull. 340, pp. 175–183, 1908.

WRIGHT, C. W., Geology and ore deposits of Copper Mountain and Kasaan Peninsula, Alaska: Prof. Paper 87, pp. 44–65, 85–108, 1915.

——— Mining in southeastern Alaska: Bull. 379, p. 152, 1909.

WRIGHT, C. W., and PAIGE, SIDNEY, Copper deposits on Kasaan Peninsula, Prince of Wales Island [Alaska]: Bull. 345, pp. 98–115, 1908.

FLUORSPAR.

BAIN, H. F., Fluorspar deposits of southern Illinois: Bull. 225, pp. 505–511, 1904.

——— Fluorspar deposits of southern Illinois: Bull. 255, pp. 1–75, 1905.

DARTON, N. H., and BURCHARD, E. F., Fluorspar near Deming, N. Mex.: Bull. 470, pp. 533–545, 1911.

IRVING, J. D., Economic resources of northern Black Hills [S. Dak.]: Prof. Paper 26, pp. 139, 158–159, 1904.

PARKER, E. W., Fluorspar: Twenty-first Ann. Rept., pt. 6 (continued), pp. 559–560, 1901.

SMITH, G. O., Our mineral reserves: Bull. 599, p. 42, 1914.

ULRICH, E. O., and SMITH, W. S. T., Lead, zinc, and fluorspar deposits of western Kentucky: Bull. 213, pp. 205–213, 1903.

——— Lead, zinc, and fluorspar deposits of western Kentucky: Prof. Paper 36, pp. 124–206, 1905.

Anonymous, fluorspar [in metallurgy]: Mineral resources for 1889 and 1890, pp. 468–472, 1892.

GRAPHITE.

ASHLEY, G. H., Rhode Island coal: Bull. 615, pp. 18–20, 33, 57, 1915.

BALL, S. H., Graphite in the Haystack Hills, Laramie County, Wyo.: Bull. 315, pp. 426–428, 1907.

BASTIN, E. S., Graphite: Mineral resources for 1908, pt. 2, pp. 717–738, 1909.

——— Graphite: Mineral resources for 1909, pt. 2, pp. 809–840, 1911.

——— Graphite: Mineral resources for 1911, pt. 2, pp. 1079–1112, 1912.

——— The production of graphite in 1913: Mineral resources for 1913, pt. 2, pp. 190–251, 1914.

BAYLEY, W. S., KÜMMEL, H. B., and SALISBURY, R. D., Geol. Atlas, Raritan [N. J.] folio (No. 191), p. 30, 1914.

BREWER, W. M., Occurrences of graphite in the South: Seventeenth Ann. Rept., pt. 3 (continued), pp. 1008–1010, 1896.

EMERSON, B. K., Geology of Massachusetts and Rhode Island: Bull. 597, p. 71, 1917.

FERGUSON, H. G., Graphite: Mineral resources for 1916, pt. 2, pp. 43–44, 49–59, 1917.

——— Graphite: Mineral resources for 1917, pt. 2, pp. 97–98, 109–117, 1918.

GALE, H. S., Supposed deposits of graphite near Brigham, Utah: Bull. 430, pp. 639–640, 1910.

HAYES, C. W., and PHALEN, W. C., Graphite deposits near Cartersville, Ga.: Bull. 340, pp. 463–465, 1908.

KEITH, ARTHUR, Geol. Atlas, Mount Mitchell [N. C.–Tenn.] folio (No. 124), p. 8, 1905.

——— Geol. Atlas, Pisgah [N. C.–S. C.] folio (No. 147), pp. 7–8, 1907.

KEMP, G. F., Graphite in the eastern Adirondacks [N. Y.]: Bull. 225, pp. 512–514, 1904.

LEE, W. T., Graphite near Raton, N. Mex.: Bull. 530, pp. 371–374, 1913.

MOFFIT, F. H., The Nome region [Alaska]: Bull. 314, pp. 139–140, 1907.

——— Geology of the Nome and Grand Central quadrangles, Alaska: Bull. 533, pp. 135–136, 1913.

PAIGE, SIDNEY, Graphite in the Llano-Burnet region, Tex.: Bull. 450, pp. 77–82, 1911.

——— Geol. Atlas, Llano-Burnet [Tex.] folio (No. 183), pp. 13–14, 1912.

PRATT, J. H., Graphite: Mineral resources for 1904, pp. 1157–1162, 1905.

SMITH, G. O., Graphite in Maine: Bull. 285, pp. 480–483, 1906.

——— Graphite: Mineral Resources for 1905, pp. 1265–1267, 1906.

——— Graphite: Mineral Resources for 1906, pp. 1139–1141, 1907.

——— Our mineral reserves: Bull. 599, pp. 37–38, 1914.

SMITH, P. S., Mineral deposits of Seward Peninsula [Alaska]: Bull. 345, p. 250, 1908.

——— Recent developments in southern Seward Peninsula [Alaska]: Bull. 379, pp. 300–301, 1909.

WINCHELL, A. N., Graphite near Dillon, Mont.: Bull. 470, pp. 528–532, 1911.

——— Mining districts of the Dillon quadrangle, Mont., and adjacent areas: Bull. 574, pp. 105–110, 1914.

GRINDING AND POLISHING MATERIALS.

ARNOLD, RALPH, and ANDERSON, ROBERT, Diatomaceous deposits of northern Santa Barbara County, Calif.: Bull. 315, pp. 438–447, 1907.

BASTIN, E. S., Feldspar and quartz deposits of Maine: Bull. 315, pp. 383–393, 1907.

——— Feldspar and quartz deposits of southeastern New York: Bull. 315, pp. 394–399, 1907.

CHAPIN, THEODORE, Mining developments in southeastern Alaska: Bull. 642, p. 104, 1916.

CHATARD, T. M., Corundum and emery: Mineral Resources for 1883–84, pp. 714–718, 1885.

DARTON, N. H., Geol. Atlas, Oelrichs [S. Dak.-Nebr.] folio (No. 85), p. 6, 1902.

——— Geol. Atlas, Camp Clarke [Nebr.] folio (No. 87), p. 4, 1903.

——— Geol. Atlas, Scotts Bluff [Nebr.] folio (No. 88), p. 5, 1903.

——— Preliminary report on the geology and water resources of Nebraska west of the one hundred and third meridian: Prof. Paper 17, pp. 35, 42–43, 1903.

HOLMES, J. A., Corundum deposits of the southern Appalachian region: Seventeenth Ann. Rept., pt. 3 (continued), pp. 935–943, 1896.

JENKS, C. N., The manufacture and use of corundum: Seventeenth Ann. Rept., pt. 3 (continued), pp. 943–950, 1896.

KATZ, F. J., Mineral Resources for 1914, pt. 2, pp. 564–568, 1915.

——— Mineral Resources for 1916, pt. 2, pp. 205–206, 209–212, 1917.

——— Mineral Resources for 1917, pt. 2, pp. 224, 227–231, 1918.

KEITH, ARTHUR, Geol. Atlas, Pisgah [N. C.-S. C.], folio (No. 147), p. 17, 1907.

PARKER, E. W., Abrasive materials: Seventeenth Ann. Rept., pt. 3, pp. 927–935, 1896.

——— Abrasive materials: Twenty-first Ann. Rept., pt. 6 (continued), pp. 463–479, 1901.

PEALE, A. C., Geol. Atlas, Three Forks [Mont.] folio (No. 24), p. 5, 1896.

PRATT, J. H., Corundum and its occurrence and distribution in the United States: Bull. 269, pp. 9–169, 1905.

RABORG, W. A., Abrasive materials: Mineral Resources for 1886, pp. 581–588, 1887.

READ, M. C., Berea grit: Mineral Resources for 1882, pp. 478–481, 1883.

SIEBENTHAL, C. E., and MESLER, R. D., Tripoli deposits near Seneca, Mo.: Bull. 340, pp. 429–437, 1908.

SMITH, G. O., Our mineral reserves: Bull. 599, pp. 38–40, 1914.

STERRETT, D. B., Precious stones: Mineral Resources for 1908, pp. 823–828, 1909.

TURNER, G. M., Novaculite: Mineral Resources for 1885, pp. 433–436, 1886.

——— Novaculites and other whetstones: Mineral Resources for 1886, pp. 589–592, 1887.

WOOLSEY, L. H., Volcanic ash near Durango, Colo.: Bull. 285, pp. 476–479, 1906.

Anonymous, Summary of abrasive materials: Mineral Resources for 1899, p. 11, 1899.

——— Abrasive materials: Nineteenth Ann. Rept., pt. 6, pp. 7–22, 1897.

GYPSUM.

ADAMS, G. I., and others, Gypsum deposits in the United States: Bull. 223, 129 pp., 21 pls., 1904.

BLAKE, W. P., Gypsum deposits in Arizona: Bull. 223, pp. 100–101, 1904.

BOUTWELL, J. M., Rock gypsum at Nephi, Utah: Bull. 225, pp. 483–487, 1904.

——— Gypsum deposits in Utah: Bull. 223, pp. 102–110, pl. 19 *A*, 1904.

BROOKS, A. H., The mining industry in 1907 [Alaska]: Bull. 345, pp. 30–31, 52, 1908.

BURCHARD, E. F., Gypsum and gypsum products: Mineral Resources for 1906, pp. 1069–1078, 1907.

——— Gypsum and gypsum products: Mineral Resources for 1908, pt. 2, pp. 622–623, 1909.

BURCHARD, E. F., Structural materials available in the vicinity of Minneapolis-Minn.: Bull. 430, p. 291, 1910.
——— Gypsum deposits in Eagle County, Colo.: Bull. 470, pp. 354–366, 1911.
——— Gypsum: Mineral Resources for 1910, pt. 2, pp. 720–731, 1911.
DARTON, N. H., Geol. Atlas, Oelrichs [S. Dak.-Nebr.] folio (No. 85), p. 6, 1902.
——— Gypsum deposits in South Dakota: Bull. 223, pp. 76–78, pl. 16 *B*, 1904.
——— Geol. Atlas, Newcastle [Wyo.-S. Dak.] folio (No. 107), p. 9, 1904.
DARTON, N. H., BLACKWELDER, E., and SIEBENTHAL, C. E., Geol. Atlas, Laramie, Sherman [Wyo.] folio (No. 173), p. 14, 1910.
DARTON, N. H., and SIEBENTHAL, C. E., Geology and mineral resources of the Laramie Basin, Wyo.: Bull. 364, pp. 56–58, 1909.
DAY, D. T., Gypsum deposits in Florida: Bull. 223, p. 48, 1904.
ECKEL, E. C., Salt and gypsum deposits of southwestern Virginia: Bull. 213, pp. 406–416, 1903.
——— Gypsum deposits in New York: Bull. 223, pp. 33–35, pl. 7, 1904.
——— Gypsum deposits in Virginia: Bull. 223, pp. 36–37, pl. 8, 1904.
——— Gypsum and gypsum products: Mineral Resources for 1905, pp. 1105–1110, 1906.
FAIRBANKS, H. W., Gypsum deposits in California: Bull. 223, pp. 119–123, pls. 19 *B*, 21, 1904.
FISHER, C. A., Geology and water resources of the Big Horn Basin, Wyo.: Prof. Paper 53, pp. 25, 58, 1906.
GALE, H. S., Salines in the Owens, Searles, and Panamint basins, southeastern California: Bull. 580, pp. 301–302, 1915.
GILBERT, G. K., Geol. Atlas, Pueblo [Colo.] folio (No. 36), p. 6, 1897.
GOULD, C. N., Gypsum deposits in Oklahoma: Bull. 223, pp. 60–67, pls. 14–15, 1904.
——— Geology and water resources of Oklahoma: Water-Supply Paper 148, pp. 17–98 passim, 1905.
——— Geology and water resources of the eastern portion of the Panhandle of Texas: Water-Supply Paper 154, pp. 20, 31–32, 1906.
——— Geology and water resources of the western portion of the Panhandle of Texas: Water-Supply Paper 191, pp. 14–16, 1907.
GRIMSLEY, G. P., Gypsum deposits in Michigan: Bull. 223, pp. 45–47, 1904.
——— Gypsum deposits in Kansas: Bull. 223, pp. 53–59, pl. 13, 1904.
HARDER, E. C., The gypsum deposits of the Palen Mountains, Riverside County, Calif.: Bull. 430, pp. 407–416, 1910.
HERRICK, H. N., Gypsum deposits in New Mexico: Bull. 223, pp. 89–99, pl. 18, 1904.
HESS, F. L., A reconnaissance of the gypsum deposits of California: Bull. 413, pp. 5–36, 1910.
——— Gypsum deposits near Cane Springs, Kern County, Calif.: Bull. 430, pp. 417–418, 1910.
HILL, B. F., Gypsum deposits in Texas: Bull. 223, pp. 68–73, 1904.
KAY, G. F., A new gypsum deposit in Iowa: Bull. 580, pp. 59–64, 1914.
KNIGHT, W. C., Gypsum deposits in Wyoming: Bull. 223, pp. 79–85, pls. 16 *A*, 17, 1904.
LAKES, ARTHUR, Gypsum deposits in Colorado: Bull. 223, pp. 86–88, 1904.
LINDGREN, WALDEMAR, Gypsum deposits in Oregon: Bull. 223, p. 111, 1904.
LOUDERBACK, G. D., Gypsum deposits in Nevada: Bull. 223, pp. 112–118, pl. 20, 1904.
LUPTON, C. T., Gypsum along the west flank of the San Rafael Swell, Utah: Bull. 530, pp. 221–231, pl. 5, 1913.
LUPTON, C. T., and CONDIT, D. D., Gypsum in the southern part of the Big Horn Mountains, Wyo.: Bull. 640, pp. 139–157, pls. 3–5, 1917.
ORTON, EDWARD, Gypsum or land plaster in Ohio: Mineral Resources for 1887, pp. 596–602, 1888.
PARKER, E. W., Gypsum: Seventeenth Ann. Rept., pt. 3, pp. 978–983, 1896.
——— Gypsum: Twenty-first Ann. Rept., pt. 6, pp. 523–530, 1901.

PEPPEL, S. V., Gypsum deposits in Ohio: Bull. 223, pp. 38–44, pls. 9–11, 1904.
RICHARDSON, G. B., Salt, gypsum, and petroleum in trans-Pecos, Texas: Bull. 260, pp. 576–577, 584–585, pl. 4, 1905.
SHALER, M. K., Gypsum in northwestern New Mexico: Bull. 315, pp. 260–265, 1907.
SIEBENTHAL, C. E., Gypsum of the Uncompahgre region, Colo.: Bull. 285, pp. 401–403, 1906.
——— Gypsum deposits of the Laramie district, Wyo.: Bull. 285, pp. 404–405, 1906.
STONE, R. W., Gypsum industry in 1912: Mineral Resources for 1912, pt. 2, pp. 637–641, 1913.
——— The gypsum industry in 1913: Mineral Resources for 1913, pt. 2, pp. 363, 372, 1914.
——— Gypsum: Mineral Resources for 1915, pt. 2, pp. 156–159, 1916.
——— Gypsum [Map showing location of mills using domestic gypsum]: Mineral Resources for 1916, pt. 2, p. 260, 1917.
——— Gypsum: Mineral Resources for 1917, pt. 2, pp. 88–95, 1918.
WEED, W. H., Gypsum deposits in Montana: Bull. 223, pp. 74–75, 1904.
——— Economic value of hot springs and hot spring deposits: Bull. 260, pp. 601–604, 1905.
WILDER, F. A., Gypsum deposits in Iowa: Bull. 223, pp. 49–52, pl. 12, 1904.
WRIGHT, C. W., Nonmetalliferous mineral resources of southeastern Alaska: Bull. 314, pp. 79–80, 1907.
——— Building stones and materials of southeastern Alaska: Bull. 345, pp. 116, 124–125, 1908.

IRON.

BALL, S. H., The Hartville iron-ore range, Wyo.: Bull. 315, pp. 190–205, 1907.
——— Titaniferous iron ores of Iron Mountain, Wyo.: Bull. 315, pp. 206–212, 1907.
BAYLEY, W. S., The Menominee iron-bearing district of Michigan: Mon. 46, 513 pp., 1904.
BAYLEY, W. S., SALISBURY, R. D., and KÜMMEL, H. B., Geol. Atlas, Raritan [N. J.] folio (No. 191), pp. 23–29, 1914.
BAYLEY, W. S., and others: Geol. Atlas, Passaic [N. J.-N. Y.] folio (No. 157), p. 6, 1908.
——— Iron ores: Twenty-first Ann. Rept., pt. 6, pp. 43–63, 1901.
BOUTWELL, J. M., Iron ores in the Uinta Mountains, Utah: Bull. 225, pp. 221–228, 1904.
BROOKS, A. H., Geologic features of Alaskan metalliferous lodes: Bull. 480, pp. 90–91, 1911.
BURCHARD, E. F., The iron ores of the Brookwood district, Ala.: Bull. 260, pp. 321–324, 1905.
——— The Clinton or red ores of the Birmingham district, Ala.: Bull. 315, pp. 130–151, 1907.
——— The brown ores of the Russellville district, Ala.: Bull. 315, pp. 152–160, 1907.
——— An estimate of the tonnage of available Clinton iron ore in the Birmingham district, Ala.: Bull. 340, pp. 308–317, 1908.
——— Tonnage estimates of Clinton iron ore in the Chattanooga region of Tennessee, Georgia, and Alabama: Bull. 380, pp. 169–187, 1909.
——— Iron ore, pig iron, and steel in 1912: Mineral Resources for 1912, pt. 1, pp. 176–190, 1913.
——— Preliminary report on the red iron ores of east Tennessee, northeast Alabama, and northwest Georgia: Bull. 540, pp. 279–328, pls. 5–6, 1914.
——— Iron ore in Cass, Marion, Morris, and Cherokee counties, Tex.: Bull. 620, pp. 69–109, 1916.
——— Iron-bearing deposits in Bossier, Caddo, and Webster parishes, La.: Bull. 620, pp. 129–150, 1916.

BURCHARD, E. F., Iron ore, pig iron, and steel in 1914: Mineral Resources for 1914, pt. 1, pp. 510–523, 1916.

——— Iron ore, pig iron, and steel in 1916: Mineral Resources for 1916, pp. 536–541, 1918.

BURCHARD, E. F., BUTTS, CHARLES, and ECKEL, E. C., Iron ores, fuels, and fluxes of the Birmingham district, Ala.: Bull. 400, 204 pp., 1910.

BUTTS, CHARLES, Economic geology of the Kittanning and Rural Valley quadrangles, Pa.: Bull. 279, pp. 171–174, 1906.

——— Geol. Atlas: Birmingham [Ala.] folio (No. 175), pp. 20–21, 1910.

——— Iron ores in the Montevallo-Columbiana region, Ala.: Bull. 470, pp. 215–230, 1911.

CLEMENTS, J. M., The Vermilion iron-bearing district of Minnesota: Mon. 45, 463 pp., 1903.

CLEMENTS, J. M., and others, The Crystal Falls iron-bearing district of Michigan: Nineteenth Ann. Rept., pt. 3, pp. 1–15, 1898.

——— The Crystal Falls iron-bearing district of Michigan: Mon. 36, 512 pp., 1899.

CROSS, WHITMAN, HOWE, ERNEST, and RANSOME, F. L., Geol. Atlas, Silverton [Colo.] folio (No. 120), pp. 28–34, 1905.

CROSS, WHITMAN, SPENCER, A. C., and RANSOME, F. L., Geol. Atlas, Rico [Colo.] folio (No. 130), pp. 14–20, 1905.

DARTON, N. H., Geol. Atlas, Franklin [Va.-W. Va.] folio (No. 32), p. 5, 1896.

DILLER, J. S., Iron ores of the Redding quadrangle, Calif.: Bull. 213, pp. 219–220, 1903.

——— Mining and mineral resources in the Redding quadrangle, Calif., in 1903: Bull. 225, p. 178, 1904.

——— So-called iron ore near Portland, Oreg.: Bull. 260, pp. 343–347, 1905.

EAKIN, H. M., Iron-ore deposits near Nome [Alaska]: Bull. 622, pp. 361–365, 1915.

ECKEL, E. C., Limonite deposits of eastern New York and western New England: Bull. 260, pp. 335–342, 1905.

——— Iron and manganese ores of the United States: Bull. 260, pp. 317–320, 1905.

——— Iron ores of northeastern Texas: Bull. 260, pp. 348–354, 1905.

——— The Clinton or red ores of northern Alabama: Bull. 285, pp. 172–179, 1906.

——— The Oriskany and Clinton ores of Virginia: Bull. 285, pp. 183–189, 1906.

EMMONS, W. H., The enrichment of sulphide ores: Bull. 529, pp. 69, 143–150, 1913.

——— The enrichment of ore deposits: Bull. 625, pp. 443–459, 1917.

GRANT, U. S., and HIGGINS, D. F., Preliminary report on the mineral resources of the southern part of Kenai Peninsula [Alaska]: Bull. 442, pp. 168–169, 1900.

HARDER, E. C., The Taylor Peak and Whitepine iron-ore deposits, Colo.: Bull. 380, pp. 188–198, 1909.

——— Iron ores, pig iron, and steel: Mineral Resources for 1908, pp. 81–118, 1909.

——— The iron ores of the Appalachian region in Virginia: Bull. 380, pp. 215–254, 1909.

——— Some iron ores of western and central California: Bull. 430, pp. 219–227, 1910.

——— Iron ores near Dayton, Nev.: Bull. 430, pp. 240–246, 1910.

——— Deposits of brown iron ore near Dillsburg, York County, Pa.: Bull. 430, pp. 250–255, 1910.

——— Iron-ore deposits of the Eagle Mountains, Calif.: Bull. 503, pp. 1–69, 1912.

HARDER, E. C., and JOHNSTON, A. W., Notes on the geology and iron ores of the Cuyuna district, Minn.: Bull. 660, pp. 1–26, pl. 1, 1918.

HARDER, E. C., and RICH, J. L., The Iron Age iron-ore deposit near Dale, San Bernardino County, Calif.: Bull. 430, pp. 228–239, pl. 2, 1910.

HAYES, C. W., Geol. Atlas, Ringgold [Ga.-Tenn.] folio (No. 2), pp. 3–4, 1894.

——— Geol. Atlas, Stevenson [Ga.-Ala.-Tenn.] folio (No. 19), p. 3, 1895.

——— Geol. Atlas, Gadsden [Ala.] folio (No. 35), p. 3, 1896.

——— Geol. Atlas, Rome [Ga.-Ala.] folio (No. 78), pp. 5–6, 1902.

——— Iron ores of the United States: Bull. 394, pp. 70–113, 1909.

Hayes, C. W., and Eckel, E. C., Iron ores of the Cartersville district, Ga.: Bull. 213, pp. 233–242, 1903.
Holden, R. J., The brown ores of the New River-Cripple Creek district, Va.: Bull. 285, pp. 190–193, 1906.
Irving, R. D., and Van Hise, C. R., The Penokee iron-bearing series of Michigan and Wisconsin: Tenth Ann. Rept., pt. 1, pp. 341–507, 1890.
——— The Penokee iron-bearing series of Michigan and Wisconsin: Mon. 19, 534 pp., 1892.
Keith, Arthur, Geol. Atlas, Chattanooga [Tenn.] folio (No. 6), pp. 3–4, 1894.
——— Geol. Atlas, Harpers Ferry [Va.-W. Va.-Md.] folio (No. 10), p. 4, 1894.
——— Geol. Atlas, Briceville [Tenn.] folio (No. 33), p. 4, 1896.
——— Iron-ore deposits of the Cranberry district, N. C.-Tenn.: Bull. 213, pp. 243–246, 1903.
——— Geol. Atlas, Cranberry [N. C.-Tenn.] folio (No. 90), p. 8, 1903.
——— Geol. Atlas, Roan Mountain [Tenn.] folio (No. 151), p. 10, 1907.
Kemp, J. F., The titaniferous iron ores of the Adirondacks: Nineteenth Ann. Rept., pt. 3, pp. 377–422, 1899.
Kindle, E. M., The iron ores of Bath County, Ky.: Bull. 285, pp. 180–182, 1906.
Knopf, Adolph, The occurrence of iron ore near Haines [Alaska]: Bull. 442, pp. 144–146, 1910.
Leith, C. K., The Mesabi iron-bearing district of Minnesota: Mon. 43, 316 pp., 33 pls., 1903.
——— Geologic work in the Lake Superior iron district during 1902: Bull. 213, pp. 247–250, 1903.
——— The Lake Superior mining region during 1903: Bull. 225, pp. 215–220, 1904.
——— Iron ores in southern Utah: Bull. 225, pp. 229–237, 1904.
——— Iron ores of the western United States and British Columbia: Bull. 285, pp. 194–200, 1906.
——— Iron-ore reserves of Michigan: Mineral Resources for 1911, pt. 1, pp. 175–190, 1912.
Leith, C. K., and Harder, E. C., The iron ores of the Iron Springs district, southern Utah: Bull. 338, 102 pp., 1908.
Lindgren, Waldemar, and Loughlin, G. F., Geology and ore deposits of the Tintic mining district, Utah: Prof. Paper 107, pp. 140, 147–148, 258–265, 1919.
Paige, Sidney, The Hanover iron-ore deposits, New Mexico: Bull. 380, pp. 199–214, 1909.
——— Preliminary report on pre-Cambrian geology and iron ores of Llano County, Tex.: Bull. 430, pp. 256–268, 1910.
——— Mineral resources of the Llano-Burnet region, Tex., with an account of the pre-Cambrian geology: Bull. 450, pp. 26–70, 1911.
——— Geol. Atlas, Silver City [N. Mex.] folio (No. 199), pp. 14–16, 1916.
Phalen, W. C., Iron ores near Ellijay, Ga.: Bull. 340, pp. 330–334, 1908.
——— Economic geology of the Kenova quadrangle, Ky., Ohio, and W. Va.: Bull. 349, pp. 122–130, 1908.
Smith, E. A., Iron ores of Alabama in their geological relations: Mineral Resources for 1882, pp. 149–161, 1883.
Smith, G. O., Our mineral reserves: Bull. 599, pp. 14–15, 1914.
Smith, P. S., The gray iron ores of Talladega County, Ala.: Bull. 315, pp. 161–184, 1907.
Smith, W. S. T., Geol. Atlas, Hartville [Wyo.] folio (No. 91), p. 5, 1903.
Spencer, A. C., Magnetite deposits of the Cornwall type in Berks and Lebanon counties, Pa.: Bull. 315, pp. 185–189, 1907.
——— Three deposits of iron ore in Cuba: Bull. 340, pp. 318–329, 1908.
——— Magnetite deposits of the Cornwall type in Pennsylvania: Bull. 359, 102 pp., 1908.

SPENCER, A, C., The Jauss iron mine, Dillsburg, Pa.: Bull. 430, pp. 247–249, 1910.
SPENCER, A. C., and others, Geol. Atlas, Franklin Furnace [N. J.] folio (No. 161), pp. 20–23, 1908.
STEBINGER, EUGENE, Titaniferous magnetite beds on the Blackfeet Indian Reservation, Mont.: Bull. 540, pp. 329–337, pl. 7, 1914.
STOSE, G. W., Geol. Atlas, Mercersburg–Chambersburg [Pa.] folio (No. 170), p. 17, 1909.
THWAITES, F. T., Recent discoveries of "Clinton" ore in eastern Wisconsin: Bull. 540, pp. 338–342, 1914.
VAN HISE, C. R., The iron-ore deposits of the Lake Superior region: Twenty-first Ann. Rept., pt. 3, pp. 305–434, 1901.
VAN HISE, C. R., and BAYLEY, W. S., Geol. Atlas, Menominee special [Mich.] folio (No. 62), pp. 7–11, 1900.
VAN HISE, C. R., BAYLEY, W. S., and SMYTH, H. L., Preliminary report on the Marquette iron-bearing district of Michigan: Fifteenth Ann. Rept., pp. 477–650, 1894.
——— The Marquette iron-bearing district of Michigan: Mon. 28, 28+608 pp., 35 pls. and atlas, 1897.
VAN HISE, C. R., and LEITH, C. K., The geology of the Lake Superior region: Mon. 52, pp. 460–572, 1911.
WEED, W. H., Geol. Atlas, Little Belt Mountains [Mont.] folio (No. 56), pp. 7–9, 1899.
——— Geology and ore deposits of the Butte district, Mont.: Prof. Paper 74, pp. 69–71, 79, 1912.

LEAD.

ADAMS, G. I., Zinc and lead deposits of northern Arkansas: Bull. 213, pp. 187–196, 1903.
ADAMS, G. I., and others, Zinc and lead deposits of northern Arkansas: Prof. Paper 24, pp. 13–14, 39, 1904.
BAIN, H. F., Lead and zinc deposits of Illinois: Bull. 225, pp. 202–207, 1904.
——— Zinc and lead deposits of northwestern Illinois: Bull. 246, 56 pp., 1905.
——— Lead and zinc resources of the United States: Bull. 260, pp. 251–261, 1905.
——— Zinc and lead deposits of the upper Mississippi Valley: Bull. 294, pp. 71–148 passim, 1906.
BAIN, H. F., VAN HISE, C. R., and ADAMS, G. I., Preliminary report on the lead and zinc deposits of the Ozark region [Mo.]: Twenty-second Ann. Rept., pt. 2, pp. 23–228, 1901.
BANCROFT, HOWLAND, Reconnaissance of the ore deposits in northern Yuma County, Ariz.: Bull. 451, pp. 44, 126, 1911.
——— Lead and zinc deposits in the Metaline mining district, northeastern Washington: Bull. 470, pp. 188–200, 1911.
——— Ore deposits of northeastern Washington: Bull. 550, pp. 26–27, 44–51, 115–116, 1914.
BASTIN, E. S., and HILL, J. M., Economic geology of Gilpin County and adjacent parts of Clear Creek and Boulder counties, Colo.: Prof. Paper 94, pp. 138, 151–152, 165–175, 1917.
BROOKS, A. H., Geologic features of Alaskan metalliferous lodes: Bull. 480, pp. 87–88, 303, 1911.
BOUTWELL, J. M., Economic geology of the Bingham mining district, Utah: Prof. Paper 38, pp. 73–385 passim, pls. 24, 25 *A*, 38 *A*, 1905.
——— Geology and ore deposits of the Park City district, Utah: Prof. Paper 77, pp. 106–108, 1912.
——— Ore deposits of Bingham, Utah: Bull. 213, pp. 113–114, 1903.
BUTLER, B. S., Geology and ore deposits of the San Francisco and adjacent districts, Utah: Prof. Paper 80, pp. 13–14, 171–172, 159–160, 117–118, 1913.

Butler, B. S., and Heikes, V. C., Notes on the Promontory district, Utah: Bull. 640, pp. 8–9, 1917.

Calkins, F. C., and Jones, E. L., jr., Economic geology of the region around Mullan, Idaho, and Saltese, Mont.: Bull. 540, pp. 177–179, 1914.

Cross, Whitman, Howe, Ernest, and Ransome, F. L., Geol. Atlas, Silverton [Colo.] folio (No. 120), pp. 29–30, 1905.

Curtis, J. S., Silver-lead deposits of Eureka, Nev.: Mon. 7, pp. 65–167 passim, 1884.

Ellis, E. E., Zinc and lead mines near Dodgeville, Wis.: Bull. 260, pp. 311–315, 1905.

Emmons, S. F., Abstract of report on geology and mining industry of Leadville, Lake County, Colo.: Second Ann. Rept., pp. 201–290, 1882.

——— Geology and mining industry of Leadville, Colo., with atlas: Mon. 12, pp. 452, 717 passim, 1886.

——— The mines of Custer County, Colo.: Seventeenth Ann. Rept., pt. 2, pp. 411–472, 1896.

Emmons, W. H., Some ore deposits in Maine and the Milan mine, N. H.: Bull. 432, pp. 21–45, 1910.

——— The enrichment of sulphide ores: Bull. 529, pp. 9–139 passim, 1917.

——— The enrichment of ore deposits: Bull. 625, pp. 356–359, 1917.

Emmons, W. H., and Larsen, E. S., A preliminary report on the geology and ore deposits of Creede, Colo.: Bull. 530, pp. 42–65, 1913.

Grant, U. S., Zinc and lead deposits of southwestern Wisconsin: Bull. 260, pp. 304–310, 1905.

Hague, Arnold, Geology of the Eureka district, Nev.: Mon. 20, pp. 310–312, 1892.

Hill, J. M., The Yellow Pine mining district, Clark County, Nev.: Bull. 540, pp. 226–274, 1914.

Hunter, J. F., Some cerusite deposits in Custer County, Colo.: Bull. 580, pp. 25–37, 1914.

Irving, J. D., and Bancroft, Howland, Geology and ore deposits in the vicinity of Lake City, Colo.: Bull. 478, pp. 56–57, 1911.

Irving, J. D., and Emmons, S. F., Economic resources of the northern Black Hills [S. Dak.]: Prof. Paper 26, pp. 53–212, 1904.

Jones, E. L., jr., Reconnaissance of the Conconully and Ruby mining districts, Wash.: Bull. 640, pp. 11–36, 1917.

Kirchoff, Charles, Lead: Twenty-first Ann. Rept., pt. 6, pp. 225–247, 1901.

Knopf, Adolph, Mineral resources of the Inyo and White Mountains, Calif.: Bull 540, pp. 81–120, 1914.

——— The Darwin silver-lead mining district, Calif.: Bull. 580, pp. 1–18, 1914.

——— The antimonial silver-lead veins of the Arabia district, Nev.: Bull. 660, pp. 249–255, 1918.

——— A geologic reconnaissance of the Inyo Range and the eastern slope of the Sierra Nevada, Calif.: Prof. Paper 110, pp. 106–118, 1918.

Lindgren, Waldemar, The gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho: Twentieth Ann. Rept., pt. 3, pp. 211, 405–406, 1900.

——— The Tres Hermanas mining district, N. Mex.: Bull. 380, pp. 123–128, 1909.

——— Resources of the United States in gold, silver, copper, lead, and zinc: Bull. 394, pp. 144–150, pl. 10, 1909.

——— The mining districts of the western United States: Bull. 507, pp. 5–43 passim, 1912.

Lindgren, Waldemar, Graton, L. C., and Gordon, C. H., The ore deposits of New Mexico: Prof. Paper 68, pp. 18–24, 51–74, 1910.

Lindgren, Waldemar, and Loughlin, G. F., Geology and ore deposits of the Tintic mining district, Utah: Prof. Paper 107, pp. 139, 143–144, 161–163, 1919.

LOUGHLIN, G. F., A reconnaissance in the Canyon Range, west-central Utah: Prof. Paper 90, pp. 59–60, 1915.

MACDONALD, D. F., Economic features of northern Idaho and northwestern Montana: Bull. 285, pp. 45–50, 1906.

PARDEE, J. T., The Dunkleberg mining district, Granite County, Mont.: Bull. 660, pp. 241–247, 1918.

——— Geology and mineral deposits of the Colville Indian Reservation, Wash.: Bull. 677, pp. 56–178, 1918.

PEPPERBERG, L. J., Notes on the mineral deposits of the Bearpaw Mountains, Mont.: Bull. 430, pp. 137–143, 1910.

RANSOME, F. L., Report on the economic geology of the Silverton quadrangle, Colo.: Bull. 182, pp. 80–81, 100, 1901.

——— Geology and ore deposits of the Breckenridge district, Colo.: Prof. Paper 75, pp. 21, 168–169, 1911.

——— Geology and ore deposits of the Coeur d'Alene district, Idaho: Prof. Paper 62, pp. 82–192, 1908.

RICHARDS, R. W., Notes on lead and copper deposits in the Bear River Range, Idaho and Utah: Bull. 470, pp. 181–187, 1911.

SHRADER, F. C., The mineral deposits of the Cerbat Range, Black Mountains, and Grand Wash Cliffs, Mohave County, Ariz.: Bull. 397, pp. 43–219 passim, 1909.

SHAW, E. W., and TROWBRIDGE, A. C., Geol. Atlas, Galena-Elizabeth [Ill.-Iowa] folio (No. 200), pp. 10–12, 1916.

SIEBENTHAL, C. E., Mineral resources of northeastern Oklahoma: Bull. 340, pp. 187–228, pl. 2, 1908.

——— Lead in 1913: Mineral Resources for 1913, pt. 1, pp. 723–725, 729–738, 1914.

——— Origin of the zinc and lead deposits of the Joplin region, Missouri, Kansas, and Oklahoma: Bull. 606, pp. 1–274, 1915.

SMITH, G. O., Note on a mineral prospect in Maine: Bull. 315, pp. 118–119, 1907.

——— Our mineral resources: Bull. 599, pp. 22–24, 1914.

SMITH, W. S. T., Lead and zinc deposits of the Joplin district, Mo.-Kans.: Bull. 213, pp. 197–204, 1903.

SMITH, W. S. T., and SIEBENTHAL, C. E., Geol. Atlas, Joplin district [Mo.-Kans.] folio (No. 148), 1907.

SPENCER, A. C., SALISBURY, R. D., and KÜMMEL, H. B., Geol. Atlas, Franklin Furnace folio (No. 161), pp. 7–8, 1908.

SPURR, J. E., Geology of the Aspen mining district, Colo., with atlas: Mon. 31, pp. 231–242, 1898.

——— The ore deposits of Monte Cristo, Wash.: Twenty-second Ann. Rept., pt. 2, pp. 777–866, 1901.

——— Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California: Bull. 208, 18–211 passim, 1903.

SPURR, J. E., and GARREY, G. H., Preliminary report on the ore deposits of the Georgetown mining district, Colo.: Bull. 260, pp. 99–120, 1905.

——— Economic geology of the Georgetown quadrangle (together with the Empire district), Colo., with general geology by S. H. Ball: Prof. Paper 63, pp. 136–166, 1908.

TOWER, G. W., and SMITH, G. O., Geology and mining industry of the Tintic district, Utah: Nineteenth Ann. Rept., pt. 3, pp. 601–767, 1899.

TOWER, G. W., SMITH, G. O., and EMMONS, S. F., Geol. Atlas, Tintic special [Utah] folio (No. 65), p. 6, 1900.

ULRICH, E. O., and SMITH, W. S. T., Lead, zinc, and fluorspar deposits of western Kentucky: Bull. 213, pp. 205–213, 1903.

——— Lead, zinc, and fluorspar deposits of western Kentucky: Prof. Paper 36, pp. 121–207, 1905.

UMPLEBY, J. B., A preliminary account of the ore deposits of the Loon Creek district, Idaho: Bull. 530, pp. 66–74, 1913.

——— Some ore deposits in northwestern Custer County, Idaho: Bull. 539, 104 pp., 1913.

——— The lead-silver deposits of the Dome district, Idaho: Bull. 540, pp. 212–222, 1914.

——— Geology and ore deposits of the Mackay region, Idaho: Prof. Paper 97, pp. 10–14, 69–86, 1917.

WEED, W. H., Geology of the Little Belt Mountains, Mont., with notes on the mineral deposits of the Neihart, Barker, Yogo, and other districts: Twentieth Ann. Rept., pt. 3, pp. 271–461, 1900.

WEED, W. H., and BARRELL, JOSEPH, Geology and ore deposits of the Elkhorn mining district, Jefferson County, Mont.: Twenty-second Ann. Rept., pt. 2, pp. 399–549, 1901.

WEED, W. H., and PIRSSON, L. V., Geology of the Castle Mountain mining district, Mont.: Bull. 139, pp. 151–162, 1896.

WINSLOW, ARTHUR, The disseminated lead ores of southeastern Missouri: Bull. 132, 31 pp., 1896.

WOLFF, J. E., Zinc and manganese deposits of Franklin Furnace, N. J.: Bull. 213, pp. 214–217, 1903.

LIMESTONE AND LIME.

ADAMS, G. I., HAWORTH, ERASMUS, and CRANE, W. R., Economic geology of the Iola quadrangle, Kans.: Bull. 238, pp. 15–20, 66–68, 1904.

BALL, S. H., Portland cement materials in eastern Wyoming: Bull. 315, pp. 234–236, 1907.

BASCOM, FLORENCE, and others, Geol. Atlas, Philadelphia [Pa.-N. J.-Del.] folio (No. 162), pp. 19–20, 1909.

BASSLER, R. S., Cement materials of the valley of Virginia: Bull. 260, pp. 531–544, 1905.

BASTIN, E. S., The lime industry of Knox County, Maine: Bull. 285, pp. 393–400, 1906.

——— Geol. Atlas, Rockland [Maine] folio (No. 158), pp. 10–13, 1908.

BAYLEY, W. S., KÜMMEL, H. B., and SALISBURY, R. D., Geol. Atlas, Raritan [N. J.] folio (No. 191), p. 30, 1914.

BURCHARD, E. F., Lime: Mineral resources for 1911, pt. 2, pp. 708–716, 1912.

——— Lime: Mineral Resources for 1910, pt. 2, pp. 617–620, 1911.

——— Concrete materials produced in the Chicago district: Bull. 340, pp. 386–397, 1908.

——— Structural materials available in the vicinity of Minneapolis, Minn.: Bull. 430, pp. 281, 283, 287–288, 1910.

——— Structural materials available in the vicinity of Austin, Tex.: Bull. 430, pp. 293–299, 1910.

——— Source of lime: Mineral Resources for 1913, pt. 2, pp. 1511–1555, 1914.

BUTTS, CHARLES, Limestone and dolomite in the Birmingham district, Ala.: Bull. 315, pp. 247–255, 1907.

——— Dolomite for flux in the vicinity of Montevallo, Shelby County, Ala.: Bull. 470, pp. 525–527, 1911.

——— Geol. Atlas, Birmingham [Ala.] folio (No. 175), pp. 21–22, 1910.

CLAPP, F. G., Limestones of southwestern Pennsylvania: Bull. 249, 52 pp., 7 pls., 1905.

CRIDER, A. F., Cement resources of northeast Mississippi: Bull. 260, pp. 510–521, 1905.

——— Geology and mineral resources of Mississippi: Bull. 283, pp. 75–84, 1906.

DALE, T. N., The calcite marble and dolomite of eastern Vermont: Bull. 589, 67 pp., 1915.

DARTON, N. H., Structural materials in parts of Oregon and Washington: Bull. 387, pp. 28–33, 1909.
——— Cement materials in Republican Valley, Nebr.: Bull. 430, pp. 383–385, 1910.
DARTON, N. H., and SIEBENTHAL, C. E., Geology and mineral resources of Laramie Basin, Wyo.: Bull. 364, pp. 14–21, 66, 1909.
DILLER, J. S., Limestone of the Redding district, Calif.: Bull. 213, p. 365, 1902.
ECKEL, E. C., and others, Portland cement materials and industry in the United States: Bull. 522, 375 pp., 1913.
FENNEMAN, N. M., Geology and mineral resources of the St. Louis quadrangle, Mo.-Ill.: Bull. 438, pp. 54–55, 1911.
GARDNER, J. H., Oolitic limestone at Bowling Green and other places in Kentucky Bull. 430, pp. 373–378, 1910.
HUBBARD, G. D., and others, Geol. Atlas, Columbus [Ohio] folio (No. 197), p. 13, 1915.
KINDLE, E. M., and TAYLOR, F. B., Geol. Atlas, Niagara [N. Y.] folio (No. 190), p. 24, 1913.
LANDES, HENRY, Cement resources of Washington: Bull. 285, pp. 377–383, 1906.
MARTIN, G. C., The Niobrara limestone of northern Colorado as a possible source of Portland cement material: Bull. 380, pp. 314–326, 1909.
PAIGE, SIDNEY, Marble prospects in the Chiricahua Mountains, Ariz.: Bull. 380, pp. 299–304, 1909.
PEPPERBERG, L. J., Cement material near Havre, Mont.: Bull. 380, pp. 328–333, 1909.
RICHARDSON, G. B., Portland cement materials near El Paso, Tex.: Bull. 340, pp. 413–414, 1908.
RIES, HEINRICH, The limestone quarries of eastern New York, western Vermont, Massachusetts, and Connecticut: Seventeenth Ann. Rept., pt. 3 (continued), pp. 795–811, 1896.
SPENCER, A. C., and others, Geol. Atlas, Franklin Furnace [N. J.] folio (No. 161), pp. 9, 26, 1908.
STOSE, G. W., Barite in southern Pennsylvania, and pure limestone in Berkeley County, W. Va.: Bull. 225, pp. 515–517, 1903.
——— Geol. Atlas, Mercersburg-Chambersburg [Pa.] folio (No. 170), pp. 11–13, 18, 1909.
UDDEN, J. A., The oolitic limestone industry at Bedford and Bloomington, Ind.: Bull. 430, pp. 335–345, 1910.
WOLFF, J. E., and BROOKS, A. H., The age of the Franklin white limestone of Sussex County, N. J.: Eighteenth Ann. Rept., pt. 2, pp. 425–458, 1897.

MAGNESITE.

DARTON, N. H., Structural materials in parts of Oregon and Washington: Bull. 387, pp. 23–28, 1909.
——— Magnesite: Mineral Resources for 1911, pt. 2, pp. 1115–1127, 1912.
GALE, H. S., Late developments of magnesite deposits in California and Nevada: Bull. 540, pp. 483–520, pl. 10, 1914.
HESS, F. L., Some magnesite deposits of California: Bull. 285, pp. 385–392, 1906.
——— The magnesite deposits of California: Bull. 355, 67 pp., 1908.
SMITH, G. O., Our mineral reserves: Bull. 599, pp. 41–42, 1914.
YALE, C. G., and GALE, H. S., Magnesite: Mineral Resources for 1912, pt. 2, pp. 1073–1076, 1913.
——— Magnesite: Mineral Resources for 1914, pt. 2, pp. 578–581, 1915.
——— Magnesite: Mineral Resources for 1916, pt. 2, pp. 391–400, 1918.
YALE, C. G., and STONE, R. W., Magnesite: Mineral Resources for 1917, pt. 2, pp. 65–79, 1918.

MANGANESE AND MANGANIFEROUS IRON ORES.

Birkinbine, John, Manganese ores: Twenty-first Ann. Rept., pt. 6, pp. 129–158, 1901.
Eckel, E. C., Iron and manganese ores of the United States: Bull. 260, pp. 317–320, 1905.
Emmons, W. H., The enrichment of ore deposits: Bull. 625, pp. 308–310, 437–443, 1917.
Emmons, W. H., and Calkins, F. C., Geology and ore deposits of the Philipsburg quadrangle, Mont.: Prof. Paper 78, pp. 209–212, 1913.
Harder, E. C., Manganese deposits of the United States: Bull. 380, pp. 255–277, 1909.
——— Manganese deposits of the United States: Bull. 427, pp. 13–283, 1910.
Hayes, C. W., Manganese ores of the Cartersville district, Ga.: Bull. 213, p. 232, 1903.
Hewett, D. F., Manganese and manganiferous ores in 1912: Mineral Resources for 1912, pt. 1, pp. 203–205, 219–220, 1913.
——— The production of manganese and manganiferous ores in 1913: Mineral Resources for 1913, pt. 1, pp. 57–59, 64–72, 1914.
——— Some manganese mines in Virginia and Maryland: Bull. 640, pp. 37–71, 1917.
——— Manganese and manganiferous ores: Mineral Resources for 1916, pt. 1, pp. 732–734, 741–752, 1918.
Hewett, D. F., and others, Possibilities for manganese ores in certain undeveloped tracts in Shenandoah Valley, Va.: Bull. 660, pp. 271–296, 1918.
Lindgren, Waldemar, and Loughlin, G. F., Geology and ore deposits of the Tintic mining district, Utah: Prof. Paper 107, pp. 140, 148, 1919.
Miser, H. D., Manganese deposits of the Caddo Gap and De Queen quadrangles, Ark.: Bull. 660, pp. 59–122, pl. 3, 1918.
Pardee, J. T., Manganese at Butte, Mont.: Bull. 690, pp. 111–130, 1918.
——— Some manganese deposits in Madison County, Mont.: Bull. 690, pp. 131–143, 1918.
Smith, G. O., Our mineral reserves: Bull. 599, pp. 15–17, 1914.
Spencer, A. C., Manganese deposits of Santiago, Cuba: Bull. 213, pp. 251–255, 1903.
Van Hise, C. R., and Leith, C. K., The geology of the Lake Superior region: Mon. 52, pp. 211–216, 488, 1911.
Weed, W. H., Geology and ore deposits of the Butte district, Mont.: Prof. Paper 74, pp. 69, 79, 1912.
Weeks, J. D., Manganese: Seventeenth Ann. Rept., pt. 3, pp. 185–186, 1896.
Wolff, J. E., Zinc and manganese deposits of Franklin Furnace, N. J.: Bull. 213, pp. 214–217, 1903.

MICA, MONAZITE, AND LITHIUM MINERALS.

Ball, S. H., Mica in the Hartville uplift, Wyo.: Bull. 315, pp. 423–425, 1907.
Bastin, E. S., Geology of the pegmatites and associated rocks of Maine, including feldspar, quartz, mica, and gem deposits: Bull. 445, pp. 51–119, 138–142 passim, 1911.
Hess, F. L., Lithium: Mineral Resources for 1909, pt. 2, pp. 649–653, 1911.
Holmes, J. A., Mica deposits in the United States: Twentieth Ann. Rept., pt. 6 (continued), pp. 691–707, 1899.
Keith, Arthur, Geol. Atlas, Pisgah [N. C.–S. C.] folio (No. 147), p. 7, 1907.
——— Geol. Atlas, Roan Mountain [Tenn.–N. C.] folio (No. 151), p. 10, 1907.
Lindgren, Waldemar, The mining districts of the Idaho Basin and the Boise Ridge, Idaho: Eighteenth Ann. Rept., pt. 3, pp. 677–679, 1898.
Nitze, H. B. C., Monazite: Sixteenth Ann. Rept., pt. 4, pp. 667–693, 1895.
Pratt, J. H., Mica: Mineral Resources for 1901, pp. 873–875, 1902.
——— Monazite: Mineral Resources for 1901, pp. 949–953, 1902.
——— Lithium: Mineral Resources for 1902, pp. 259–260, 1904.
——— Monazite: Mineral Resources for 1903, pp. 1163–1169, 1904.

PRATT, J. H. Mica: Mineral Resources for 1904, pp. 1175–1181, 1905.
——— Monazite: Mineral Resources for 1904, pp. 1209–1212, 1905.
SCHALLER, W. T., Lithium minerals: Mineral Resources for 1916, pt. 1, pp. 7–17, 1917.
——— Thorium minerals: Mineral Resources for 1916, pt. 2, pp. 223–224, 227–236, 1917.
——— Mica: Mineral Resources for 1916, pt. 2, pp. 304–308, 1917.
——— Mica: Mineral Resources for 1917, pt. 2, pp. 190–195, 1918.
SCHRADER, F. C., An occurrence of monazite in northern Idaho: Bull. 430, pp. 184–190, 1910.
STERRETT, D. B., Mica deposits of western North Carolina: Bull. 315, pp. 400–422, 1907.
——— Monazite and zircon: Mineral Resources for 1906, pp. 1196–1205, 1907.
——— Monazite deposits of the Carolinas: Bull. 340, pp. 272–285, 1908.
——— Monazite and zircon: Mineral Resources for 1908, pt. 2, pp. 791–792, 1909.
——— Mica: Mineral Resources for 1908, pt. 2, pp. 743–752, 1909.
——— Mica deposits of South Dakota: Bull. 380, pp. 382–397, 1909.
——— Mica deposits of North Carolina: Bull. 430, pp. 593–638, pl. 14, 1910.
——— Mica: Mineral Resources for 1909, pt. 2, pp. 845–853, 1911.
——— Monazite and zircon: Mineral Resources for 1909, pt. 2, pp. 897–903, 1911.
——— Mica in 1912: Mineral Resources for 1912, pt. 2, pp. 1079–1086, 1913.
——— Mica in Idaho, New Mexico, and Colorado: Bull. 530, pp. 375–390, 1913.
——— Some deposits of mica in the United States: Bull. 580, pp. 65–125, 1914.
——— Mica: Mineral Resources for 1914, pt. 2, pp. 67–74, 1916.
Anonymous, Lithium: Mineral Resources for 1900, pp. 239–243, 1901.

NITRATES.

GALE, H. S., Nitrate deposits: Bull. 523, pp. 5–36, 1912.
——— Other investigations of saline deposits: Mineral Resources for 1912, pt. 2, pp. 893–895, 1913.
MANSFIELD, G. R., Nitrate deposits in southern Idaho and eastern Oregon: Bull. 620, pp. 19–44, pls. 2–3, 1916.
RICHARDS, R. W., Niter near Melrose, Mont.: Bull. 540, pp. 470–473, 1914.
SMITH, G. O., Our mineral reserves: Bull. 599, p. 36, 1914.

PETROLEUM.

ADAMS, G. I., Oil and gas fields of the western interior and northern Texas coal measures and of the upper Cretaceous and Tertiary of the western Gulf coast: Bull. 184, 64 pp., 1901.
ANDERSON, ROBERT, Geology and oil prospects of the Reno region, Nev.: Bull. 381, pp. 475–489, 1910.
——— Two areas of oil prospecting in Lyon County, western Nevada: Bull. 381, pp. 490–493, 1910.
——— Preliminary report on the geology and the oil prospects of the Cantua-Panoche region, Calif.: Bull. 431, pp. 58–87, 1911.
——— Preliminary report on the geology and possible oil resources of the south end of the San Joaquin Valley, Calif.: Bull. 471, pp. 106–136, pl. 10, 1912.
ANDERSON, ROBERT, and PACK, R. W., Geology and oil resources of the west border of the San Joaquin Valley north of Coalinga, Calif.: Bull. 603, 220 pp., 1915.
ARNOLD, RALPH, The Salt Lake oil field near Los Angeles, Calif.: Bull. 285, pp. 357–361, 1906.
——— The Miner ranch oil field, Contra Costa County, Calif.: Bull. 340, pp. 339–342, 1908.
——— Geology and oil resources of the Summerland district, Santa Barbara County, Calif.: Bull. 321, 93 pp., 17 pls., 1907.

ARNOLD, RALPH, and ANDERSON, ROBERT, Preliminary report on the Santa Maria oil district, Santa Barbara County, Calif.: Bull. 317, 69 pp., 1907.
——— Geology and oil resources of the Santa Maria oil district, Santa Barbara County, Calif.: Bull. 322, 161 pp., 26 pls., 1907.
——— Preliminary report on the Coalinga oil district, Fresno and Kings counties, Calif.: Bull. 357, 142 pp., 1908.
——— Geology and oil resources of the Coalinga district, Calif.: Bull. 398, 354 pp., 52 pls., 1910.
ARNOLD, RALPH, and JOHNSON, H. R., Preliminary report on the McKittrick-Sunset oil region, Kern and San Luis Obispo counties, Calif.: Bull. 406, 225 pp., 5 pls., 1910.
ASHLEY, G. H., Oil resources of black shales of the eastern United States: Bull. 641, pp. 311–324, 1917.
ASHLEY, G. H., and CAMPBELL, M. R., Geologic structure of the Punxsutawney, Curwensville, Houtzdale, Barnesboro, and Patton quadrangles, central Pennsylvania: Bull. 531, pp. 69–89, pls, 7–8, 1913.
ATWOOD, W. W., Geology and mineral resources of parts of the Alaska Peninsula: Bull. 467, pp. 120–124, 1911.
BALL, M. W., Petroleum withdrawals and restorations affecting the public domain: Bull. 623, 427 pp., 1916.
BARNETT, V. H., The Douglas oil and gas field, Converse County, Wyo.: Bull. 541, pp. 49–88, pl. 4, 1914.
——— The Moorcroft oil field, Crook County, Wyo.: Bull. 581, pp. 83–104, pl. 3, 1915.
——— Possibilities of oil in the Big Muddy dome, Converse and Natrona counties, Wyo.: Bull. 581, pp. 105–117, pl. 4, 1915.
BEAL, C. H., Geologic structure in the Cushing oil and gas field, Okla., and its relation to the oil, gas, and water: Bull. 658, 64 pp., 1917.
BECKER, G. F., Relations between local magnetic disturbances and the genesis of petroleum: Bull. 401, 24 pp., 1909.
BONINE, C. A., Anticlines in the Clinton sand near Wooster, Wayne County, Ohio: Bull. 621, pp. 87–98, pl. 13, 1916.
BOUTWELL, J. M., Oil and asphalt prospects in Salt Lake basin, Utah: Bull. 260, pp. 468–479, 1905.
BOWEN, C. F., Possibilities of oil in the Porcupine dome, Rosebud County, Mont.: Bull. 621, pp. 61–70, pl. 10, 1916.
——— Phosphatic oil shales near Dill and Dillon, Beaverhead County, Mont.: Bull. 661, pp. 315–328, 1918.
——— Structure and oil and gas resources of the Osage Reservation, Okla.: Bull. 686, pp. 17–26, 43–58, 137–148, 1918.
——— Anticlines in a part of the Musselshell Valley, Mont.: Bull. 691, pp. 208–209, 1918.
BOWMAN, I., Well-drilling methods: Water-Supply Paper 257, pp. 100–117, 1911.
BRANNER, J. C., NEWSOM, J. F., and ARNOLD, RALPH, Geol. Atlas, Santa Cruz [Calif.] folio (No. 163), p. 11, 1909.
BUTTS, CHARLES, Economic geology of the Kittanning and Rural Valley quadrangles, Pa.: Bull. 279, pp. 102–161, 1906.
——— Geol. Atlas, Warren [Pa.-N. Y.] folio (No. 172), pp. 10–11, 1910.
BUTTS, CHARLES, and LEVERETT, FRANK, Geol. Atlas, Kittanning [Pa.] folio (No. 115), pp. 13–14, 1904.
CALVERT, W. R., Geology of the Upper Stillwater Basin, Stillwater and Carbon counties, Mont., with special reference to coal and oil: Bull. 641, pp. 199–214, pls. 20–21, 1917.

CAMPBELL, M. R., Geol. Atlas, Standingstone [Tenn.] folio (No. 53), p. 4, 1899.
——— Geol. Atlas, Charleston [W. Va.] folio (No. 72), p. 6, 1901.
——— Geol. Atlas, Masontown-Uniontown [Pa.] folio (No. 82), pp. 19–20, 1902.
CLAPP, F. G., The Nineveh and Gordon oil sands in western Greene County, Pa.: Bull. 285, pp. 362-366, 1906.
——— Economic geology of the Amity quadrangle, eastern Washington County, Pa.: Bull. 300, pp. 42–87, 1907.
——— Geol. Atlas, Amity [Pa.] folio (No. 144), pp. 13–14, 1907.
——— Geol. Atlas, Rogersville [Pa.] folio (No. 146), pp. 10–12, 1907.
CLARK, F. R., Structure and oil and gas resources of the Osage Reservation, Okla.: Bull. 686, pp. 91–118, 1918.
COLLIER, A. J., The Bowdoin dome, Mont., a possible reservoir of oil and gas: Bull. 661, pp. 133–209, pl. 16, 1918.
——— The Nesson anticline, Williams County, N. Dak.: Bull. 691, pp. 216–217, 1918.
CONDIT, D. D., Oil and gas in the northern part of the Cadiz quadrangle, Ohio: Bull. 541, pp. 9–17, pl. 1, 1914.
——— Structure of the Berea oil sand in the Summerfield quadrangle, Guernsey, Noble, and Monroe counties, Ohio: Bull. 621, pp. 217–231, pls. 22–23, 1916.
——— Structure of the Berea oil sand in the Woodsfield quadrangle, Belmont, Monroe, Noble, and Guernsey counties, Ohio: Bull. 621, pp. 233–249, pls. 24–25, 1916.
DARTON, N. H., and SIEBENTHAL, C. E., Geology and mineral resources of the Laramie Basin, Wyo.: Bull. 364, pp. 73–74, 1909.
DAY, D. T., Analyses of crude petroleum from Oklahoma and Kansas: Bull. 381, pp. 494–503, 1910.
——— The petroleum resources of the United States: Bull. 394, pp. 30–50, pls. 2–5, 1909.
ELDRIDGE, G. H., The petroleum fields of California: Bull. 213, pp. 306–321, 1902.
ELDRIDGE, G. H., and ARNOLD, RALPH, The Santa Clara Valley, Puente Hills, and Los Angeles oil districts, southern California: Bull. 309, 266 pp., 1907.
EMERY, W. B., Structure and oil and gas resources of the Osage Reservation, Okla.: Bull. 686, pp. 1-9, 1918.
ENGLISH, W. A., Geology and oil prospects of Cuyama Valley, Calif.: Bull. 621, pp. 191–215, pls. 19–21, 1916.
——— Geology and oil prospects of the Salinas Valley–Parkfield area, Calif.: Bull. 691, pp. 235–250, 1918.
FATH, A. E., An anticlinal fold near Billings, Noble County, Okla.: Bull. 641, pp. 121–138, pl. 9, 1917.
——— Structure of the northern part of the Bristow quadrangle, Creek County, Okla., with reference to petroleum and natural gas: Bull. 661, pp. 69–99, pls. 3–6, 1918.
FENNEMAN, N. M., The Boulder, Colo., oil field: Bull. 213, pp. 322–332, 1902.
——— Structure of the Boulder oil field, Colo.: Bull. 225, pp. 383–391, 1903.
——— The Florence, Colo., oil field: Bull. 260, pp. 436–440, 1905.
——— Oil fields of the Texas-Louisiana Gulf coast: Bull. 260, pp. 459–467, 1905.
——— Geology of the Boulder district, Colo.: Bull. 265, pp. 76–98, 1905.
——— Oil fields of the Texas-Louisiana Gulf Coastal Plain: Bull. 282, 146 pp., 1906.
FISHER, C. A., Geol. Atlas, Nepesta [Colo.] folio (No. 135), p. 5, 1906.
FULLER, M. L., The Gaines oil field of northern Pennsylvania: Twenty-second Ann. Rept., pt. 3, pp. 573–627, 1901.
——— Asphalt, oil, and gas in southwestern Indiana: Bull. 213, pp. 333–334, 1902.
FULLER, M. L., and ALDEN, W. C., Geol. Atlas, Gaines [Pa.-N. Y.] folio (No. 92), pp. 7–8, 1903.
FULLER, M. L., LINES, E. F., and VEATCH, A. C., Record of deep-well drilling for 1904: Bull. 264, 106 pp., 1905.

FULLER, M. L., and SANFORD, SAMUEL, Record of deep-well drilling for 1905: Bull. 298, 299 pp., 1906.

GALE, H. S., Geology of the Rangely oil district, Rio Blanco County, Colo.: Bull. 350, 61 pp., 4 pls., 1908.

GILPIN, J. E., and BRANSKY, O. E., The diffusion of crude petroleum through fuller's earth, with notes on its geologic significance: Bull. 475, 50 pp., 1911.

GILPIN, J. E., and CRAM, M. P., The fractionation of crude petroleum by capillary diffusion: Bull. 365, 33 pp., 1908.

GORDON, C. H., Geology and underground waters of northeastern Texas: Water-Supply Paper 276, pp. 57–59, 1911.

——— Geology and underground waters of the Wichita region, north-central Texas: Water-Supply Paper 317, pp. 25, 47–50, 1913.

GREGORY, H. E., The San Juan oil field, San Juan County, Utah: Bull. 431, pp. 11–25, pl. 2, 1911.

GRISWOLD, W. T., The Berea grit oil sand in the Cadiz quadrangle, Ohio: Bull. 198, 43 pp., 1902.

——— Structural work during 1901 and 1902 in the eastern Ohio oil fields: Bull. 213, pp. 336–344, 1902.

——— Hyner gas pool, Clinton County, Pa.: Bull. 225, pp. 392–395, 1903.

——— Structure of the Berea oil sand in the Flushing quadrangle, Harrison, Belmont, and Guernsey counties, Ohio: Bull. 346, 30 pp., 1908.

GRISWOLD, W. T., and MUNN, M. J., Geology of the oil and gas fields in Steubenville, Burgettstown, and Claysville quadrangles, Ohio, W. Va., and Pa.: Bull. 318, 196 pp., 13 pls., 1907.

HANCOCK, E. T., Geology and oil and gas prospects of the Lake Basin field, Mont.: Bull. 691, pp. 141–147, pls. 16–23, 1918.

HARRIS, G. D., Oil and gas in Louisiana: Bull. 429, 192 pp., 22 pls., 1910.

HAWORTH, E., and ADAMS, G. I., Economic geology of the Iola quadrangle, Kans.: Bull. 238, pp. 30–40, 61, 1904.

HAYES, C. W., Oil fields of the Texas-Louisiana Gulf Coastal Plain: Bull. 213, pp. 345–352, 1902.

HAYES, C. W., and KENNEDY, WILLIAM, Oil fields of the Texas-Louisiana Gulf Coastal Plain: Bull. 212, 174 pp., 1903.

HEALD, K. C., The oil and gas geology of the Foraker quadrangle, Osage County, Okla.: Bull. 641, pp. 17–47, pls. 2–3, 1917.

——— Structure and oil and gas resources of the Osage Reservation, Okla.: Bull. 686, pp. 27–41, 129–135, 1918.

——— Geologic structure of the northwestern part of the Pawhuska quadrangle, Okla.: Bull. 691, pp. 87–100, pls. 13–15, 1918.

HEWETT, D. F., The Shoshone River section, Wyo.: Bull. 541, pp. 89–113, pl. 5, 1914.

HEWETT, D. F., and LUPTON, C. T., Anticlines in the southern part of the Big Horn Basin, Wyo.: Bull. 656, 192 pp., 32 pls., 1917.

HOPKINS, O. B., Structure of the Vicksburg-Jackson area, Miss., with special reference to oil and gas: Bull. 641, pp. 93–120, pl. 8, 1917.

——— Oil and gas possibilities of the Hatchetigbee anticline, Ala.: Bull. 661, pp. 281–313, pls. 26–29, 1918.

——— The Palestine salt dome, Anderson County, Tex.: Bull. 661, pp. 253–270, pls. 22–23, 1918.

——— The Brenham salt dome, Washington and Austin counties, Tex.: Bull. 661, pp. 271–280, pls. 24–25, 1918.

——— Structure and oil and gas resources of the Osage Reservation, Okla.: Bull. 686, pp. 75–90, 1918.

KEITH, ARTHUR, Geol. Atlas, Wartburg [Tenn.] folio (No. 40), pp. 3–4, 1896.

LLOYD, E. R., and MATHER, K. F., Structure and oil and gas resources of the Osage Reservation, Okla.: Bull. 686, pp. 119-127, 1918.

LUPTON, C. T., Oil and gas near Green River, Grand County, Utah: Bull. 541, pp. 115-133, pl. 6, 1914.

——— Oil and gas in the western part of the Olympic Peninsula, Wash.: Bull. 581, pp. 23-81, pl. 2, 1915.

——— Oil and gas near Basin, Big Horn County, Wyo.: Bull. 621, pp. 157-190, pls. 17-18, 1916.

MARTIN, G. C., Petroleum fields of Alaska and the Bering River coal fields: Bull. 225, pp. 365-382, 1903.

——— The petroleum fields of the Pacific coast of Alaska: Bull. 250, 64 pp., 1905.

——— Notes on the petroleum fields of Alaska: Bull. 259, pp. 128-139, 1905.

——— Petroleum at Controller Bay [Alaska]: Bull. 314, pp. 89-103, 1907.

——— Geology and mineral resources of the Controller Bay region, Alaska: Bull. 335, pp. 112-130, 1908.

MATSON, G. C., The Caddo oil and gas field, La. and Tex.: Bull. 619, 62 pp., 1916.

MATSON, G. C., and HOPKINS, O. B., The De Soto-Red River oil and gas field, La.: Bull. 661, pp. 101-140, pls. 7-10, 1918.

——— The Corsicana oil and gas field, Tex.: Bull. 661, pp. 211-252, pls. 17-21, 1918.

MISER, H. D., and PURDUE, A. H., Asphalt deposits and oil conditions in southwestern Arkansas: Bull. 691, pp. 280-292, 1918.

MUNN, M. J., Oil and gas fields of the Carnegie quadrangle, Pa.: Bull. 456, 99 pp., 1911.

——— Geol. Atlas, Sewickley [Pa.] folio (No. 176), pp. 10-14, 1911.

——— Geol. Atlas, Claysville [Pa.] folio (No. 180), pp. 10-12, 1912.

——— The Campton oil pool, Ky.: Bull. 471, pp. 9-17, pls. 1-2, 1912.

——— Oil and gas development in Knox County, Ky.: Bull. 471, pp. 18-29, pls. 3-4, 1912.

——— The Fayette gas field, Ala.: Bull. 471, pp. 30-55, 1912.

——— The Menifee gas field and the Ragland oil field, Ky.: Bull. 531, pp. 9-26, pls. 1-4, 1913.

——— Reconnaissance of the Grandfield district, Okla.: Bull. 547, pp. 74-83, 1914.

——— Reconnaissance of oil and gas fields in Wayne and McCreary counties, Ky.: Bull. 579, 105 pp., 6 pls., 1914.

OLIPHANT, F. H., Petroleum [Texas]: Nineteenth Ann. Rept., pp. 102-104, 1898.

——— Petroleum: Mineral Resources for 1900, pp. 571-584, 1901.

ORTON, EDWARD, The Trenton limestone as a source of petroleum and inflammable gas in Ohio and Indiana: Eighth Ann. Rept., pt. 2, pp. 475-662, 1889.

PACK, R. W., Reconnaissance of the Barstow-Kramer region, Calif.: Bull. 541, pp. 141-154, pl. 7, 1914.

PACK, R. W., and ENGLISH, W. A., Geology and oil prospects of Waltham, Priest, Bitterwater, and Peachtree valleys, Calif.: Bull. 581, pp. 119-160, pl. 5, 1915.

PAIGE, SIDNEY, Mineral resources of the Llano-Burnet region, Tex., with an account of the pre-Cambrian geology: Bull. 450, pp. 93-94, 1911.

PHALEN, W. C., Geol. Atlas, Kenova [Ky.-Ohio-W. Va.] folio (No. 184), p. 16, 1912.

PHINNEY, A. J., The natural gas field of Indiana: Eleventh Ann. Rept. pt. 1, pp. 579-742, 1891.

RICHARDSON, G. B., Salt, gypsum, and petroleum in trans-Pecos Texas: Bull. 260, pp. 573-578, 580-584, pl. 4, 1905.

——— Petroleum in southern Utah: Bull. 340, pp. 343-347, 1908.

——— Petroleum near Dayton, N. Mex.: Bull. 541, pp. 135-140, 1914.

ROGERS, G. S., Chemical relations of the oil-field waters in San Joaquin Valley, Calif.: Bull. 653, 119 pp., 1917.

SCHRADER, F. C., Geol. Atlas, Independence [Kans.] folio (No. 159), pp. 5-6, 1908.

SCHRADER, F. C., and HAWORTH, ERASMUS, Oil and gas of the Independence quadrangle, Kans.: Bull. 260, pp. 446–458, 1905.

——— Economic geology of the Independence quadrangle, Kans.: Bull. 296, pp. 20–39, 95–123, 1906.

SCHULTZ, A. R., The Labarge oil field, central Uinta County, Wyo.: Bull. 340, pp. 364–373, pl. 4, 1908.

——— Geology and geography of a portion of Lincoln County, Wyo.: Bull. 543, pp. 115–121, 1914.

SHAW, E. W., The Irvine oil field, Estill County, Ky.: Bull. 661, pp. 141–192, pls. 11–15, 1918.

SHAW, E. W., and MUNN, M. J., Coal, oil, and gas of the Foxburg quadrangle, Pa.: Bull. 454, 85 pp., 10 pls., 1911.

——— Geol. Atlas, Burgettstown-Carnegie [Pa.] folio (No. 177), pp. 11–14, 1911.

SHAW, E. W., LINES, E. F., and MUNN, M. J., Geol. Atlas, Foxburg-Clarion [Pa.] folio (No. 178), pp. 14–16, 1911.

SMITH, C. D., The Glenn oil and gas pool and vicinity, Okla.: Bull. 541, pp. 34–38, pl. 3, 1914.

——— Structure of the Fort Smith-Poteau gas field, Ark.-Okla.: Bull. 541, pp. 29–33, pl. 2, 1914.

SMITH, G. O., Our mineral reserves: Bull. 599, pp. 12–13, 47, 1914.

SMITH, G. O., and others, The classification of the public lands: Bull. 537, pp. 111–123, 1913.

STEBINGER, EUGENE, Possibilities of oil and gas in north-central Montana: Bull. 641, pp. 49–91, pls. 4–7, 1917.

——— Oil and gas geology of the Birch Creek-Sun River area, northwestern Montana: Bull. 691, pp. 167–184, 1918.

STEPHENSON, L. W., A contribution to the geology of northeastern Texas and southern Oklahoma: Prof. Paper 120, pp. 161–163, 1918.

STONE, R. W., Oil and gas of eastern Greene County, Pa.: Bull. 225, pp. 396–412, 1903.

——— Mineral resources of the Elders Ridge quadrangle, Pa.: Bull. 256, 86 pp., 1905.

——— Geol. Atlas, Waynesburg [Pa.] folio (No. 121), p. 12, 1905.

STONE, R. W., and CLAPP, F. G., Oil and gas fields of Greene County, Pa.: Bull. 304, 110 pp., 1907.

TAFF, J. A., Geol. Atlas, Muscogee [Okla.] folio (No. 132), p. 6, 1906.

TAFF, J. A., and REED, W. J., The Madill oil pool, Okla.: Bull. 381, pp. 504–513, pl. 23, 1910.

TAFF, J. A., and SHALER, M. K., Notes on the geology of the Muscogee oil field, Ind. T. [Okla.]: Bull. 260, pp. 441–445, 1905.

VEATCH, A. C., Geography and geology of a portion of southwestern Wyoming, with special reference to coal and oil: Prof. Paper 56, 178 pp., 1907.

WASHBURNE, C. W., Development in the Boulder oil field, Colo.: Bull. 381, pp. 514–516, 1910.

——— The Florence oil field, Colo.: Bull. 381, pp. 517–544, pl. 24, 1910.

——— Gas and oil prospects near Vale, Oreg., and Payette, Idaho: Bull. 431, pp. 26–55, pl. 3, 1911.

——— Reconnaissance of the geology and oil prospects of northwestern Oregon: Bull. 590, 111 pp., 1914.

WEGEMANN, C. H., The Powder River oil field, Wyo.: Bull. 471, pp. 56–75, pl. 7, 1912.

——— Anticlinal structure in parts of Cotton and Jefferson counties, Okla.: Bull. 602, pp. 9–100, 1915.

——— A reconnaissance for oil near Quanah, Hardeman County, Tex.: Bull. 621, pp. 109–115, pl. 14, 1916.

——— A reconnaissance in Palo Pinto County, Tex., with special reference to oil and gas: Bull. 621, pp. 51–59, 1916.

WEGEMANN, C. H., The Salt Creek oil field, Wyo.: Bull. 670, 52 pp., 7 pls., 1917.

WEGEMANN, C. H., and HEALD, K. C., The Healdton oil field, Carter County, Okla.: Bull. 621, pp. 13-30, pls. 3-5, 1916.

WEGEMANN, C. H., and HOWELL, R. W., The Lawton oil and gas field, Okla.: Bull. 621, pp. 71-85, pls. 11-12, 1916.

WINCHESTER, D. E., Oil shale in northwestern Colorado and adjacent areas: Bull. 641, pp. 139-198, pls. 10-19, 1917.

——— Structure and oil and gas resources of the Osage Reservation, Okla.: Bull. 686, pp. 11-15, 1918.

——— Oil shale of the Uinta Basin, northeastern Utah, and Results of dry distillation of miscellaneous shale samples: Bull. 691, pp. 27-55, pls. 5-12, 1918.

WINCHESTER, D. E., HEALD, K. C., and others, Structure and oil and gas resources of the Osage Reservation, Okla.: Bull. 686, pp. 59-73, 1918.

WOOD, R. H., Oil and gas development in north-central Oklahoma: Bull. 531, pp. 27-53, pl. 5, 1913.

WOODRUFF, E. G., Geology of the San Juan oil field, Utah: Bull. 471, pp. 76-104, pls. 8-9, 1912.

——— Geology and petroleum resources of the De Beque oil field, Colo.: Bull. 531, pp. 54-68, pl. 6, 1913.

WOODRUFF, E. G., and DAY, D. T., Oil shale of northwestern Colorado and northeastern Utah: Bull. 581, pp. 1-21, pl. 1, 1915.

WOODRUFF, E. G., and WEGEMANN, C. H., The Lander and Salt Creek oil fields, Wyo.: Bull. 452, 87 pp., 12 pls., 1911.

WOOLSEY, L. H., Economic geology of the Beaver quadrangle, Pa.: Bull. 286, pp. 76-83, 1906.

——— Geol. Atlas, Beaver [Pa.] folio (No. 134), pp. 13-14, 1906.

PHOSPHATE ROCK.

BLACKWELDER, ELIOT, Phosphate deposits east of Ogden, Utah: Bull. 430, pp. 536-551, 1910.

——— A reconnaissance of the phosphate deposits in western Wyoming: Bull. 470 pp. 452-481, pl. 17, 1911.

BOWEN, C. F., Phosphatic oil shales near Dell and Dillon, Beaverhead County, Mont.: Bull. 661, pp. 317-319, 1918.

CALKINS, F. C., and EMMONS, W. H., Geol. Atlas, Philipsburg [Mont.] folio (No. 196), p. 25, 1915.

ECKEL, E. C., Recently discovered extension of Tennessee white-phosphate field: Mineral Resources for 1900, pp. 812-813, 1901.

——— The white phosphate of Decatur County, Tenn.: Bull. 213, pp. 424-425, 1903.

EMMONS, W. H., The enrichment of ore deposits: Bull. 625, pp. 499-501, 1917.

GALE, H. S., Rock phosphate near Melrose, Mont.: Bull. 470, pp. 440-451, 1911.

GALE, H. S., and RICHARDS, R. W., Preliminary report on the phosphate deposits in southeastern Idaho and adjacent parts of Wyoming and Utah: Bull. 430, pp. 457-535, pls. 4-13, 1910.

HAYES, C. W., The Tennessee phosphates: Sixteenth Ann. Rept., pt. 4, pp. 610-630, 1895.

——— The Tennessee phosphates: Seventeenth Ann. Rept., pt. 2, pp. 519-550, 1896.

——— A brief reconnaissance of the Tennessee phosphate field: Twentieth Ann. Rept., pt. 6, pp. 633-638, 1899.

——— Tennessee white phosphate: Twenty-first Ann. Rept., pt. 3, pp. 473-485, 1901.

——— Origin and extent of the Tennessee white phosphates: Bull. 213, pp. 418-423, 1903.

HICKS, W. B., Simple tests for phosphates: Mineral Resources for 1916, pt. 2, pp. 242-243, 1917.

IHLSENG, M. C., A phosphate prospect in Pennsylvania: Seventeenth Ann. Rept., pt. 3, pp. 955-957, 1896.

MANSFIELD, G. R., A reconnaissance for phosphate in the Salt River Range, Wyo.: Bull. 620, pp. 331–349, pl. 12, 1916.

MATSON, G. C., The phosphate deposits of Florida: Bull. 605, 101 pp., 1915.

MEMMINGER, C. G., Commercial development of the Tennessee phosphates: Sixteenth Ann. Rept., pt. 4, pp. 631–635, 1895.

MOSES, O. A., The phosphate deposits of South Carolina: Mineral Resources for 1882, pp. 504–517, 1883.

PARDEE, J. T., Some further discoveries of rock phosphate in Montana: Bull. 530, pp. 285–391, 1913.

——— The Garrison and Philipsburg phosphate fields, Mont.: Bull. 640, pp. 195–228, pls. 8–9, 1917.

PENROSE, R. A. F., Nature and origin of deposits of phosphate of lime: Bull. 46, 143 pp., 1888.

PHALEN, W. C., Phosphate rock in 1912: Mineral Resources for 1912, pt. 2, pp. 861–875, 1913.

——— Phosphate rock: Mineral resources for 1915, pt. 2, pp. 234–239, 242, 1916.

PURDUE, A. H., Developed phosphate deposits of northern Arkansas: Bull. 315, pp. 463–473, 1907.

RICHARDS, R. W., and MANSFIELD, G. R., Preliminary report on a portion of the Idaho phosphate reserve: Bull. 470, pp. 371–439, pls. 9–16, 1911.

——— Geology of the phosphate deposits northeast of Georgetown, Idaho: Bull. 577. 76 pp., 1914.

ROGERS, G. S., Phosphate deposits of South Carolina: Bull. 580, pp. 183–220, pl. 2, 1915.

SCHULTZ, A. R., Geology and geography of a portion of Lincoln County, Wyo.: Bull, 543, pp. 131-134, 1914.

——— A geologic reconnaissance for phosphate and coal in southeastern Idaho and western Wyoming: Bull. 680, pp. 37–64, 1918.

——— A geologic reconnaissance of the Uinta Mountains, northern Utah: Bull. 690, pp. 31–94, pls. 4–5, 1918.

SCHULTZ, A. R., and RICHARDS, R. W., A geologic reconnaissance in southeastern Idaho: Bull. 530, pp. 267–284, 1913.

SMITH, G. O., Our mineral reserves: Bull. 599, pp. 33–35, 1914.

SMITH, G. O., and others, The classification of the public lands: Bull. 537, pp. 123–134, 1913.

STONE, R. W., Phosphate rock: Mineral Resources for 1916, pt. 2, pp. 33–38, 41, 1917.

——— Phosphate rock: Mineral resources for 1917, pt. 2, pp. 12–13, 1918.

STONE, R. W., and BONINE, C. A., The Elliston phosphate field, Mont.: Bull. 580, pp. 373–383, pl. 9, 1915.

STOSE, G. W., Phosphorus ore at Mount Holly Springs, Pa.: Bull. 315, pp. 474–483, 1907.

——— Phosphorus: Mineral resources for 1906, pp. 1084–1090, 1907.

——— Phosphate deposits in southwestern Virginia: Bull. 540, pp. 383–396, 1914.

STUBBS, W. C., Phosphates of Alabama: Mineral resources for 1883–84, pp. 794–803, 1885.

VAN HORN, F. B., The phosphate deposits of the United States: Bull. 394, pp. 157–171, 1909.

——— Phosphate rock: Mineral Resources for 1910, pt. 2, pp. 735–738, 1911.

——— Phosphate rock: Mineral Resources for 1911, pt. 2, pp. 877-881, 1912.

WEEKS, F. B., Phosphate deposits in the western United States: Bull. 340, pp. 441–447, 1908.

WEEKS, F. B., and FERRIER, W. F., Phosphate deposits in western United States: Bull. 315, pp. 449–462, pl. 4, 1907.

WILBER, F. A., Greensand marls in the United States: Mineral Resources for 1882, pp. 522–526, 1883.

Anonymous, Fertilizers: Phosphate rock, Florida: Mineral Resources for 1889 and 1890, pp. 451–454, 1892.

PLATINUM.

BANCROFT, HOWLAND, Platinum in southeastern Nevada: Bull. 430, pp. 192–199, 1910.

EMMONS, S. F., Platinum in copper ores in Wyoming: Bull. 213, pp. 94–97, 1903.

HILL, J. M., Platinum and allied metals: Mineral Resources for 1916, pt. 1, pp. 6–20, 1917.

——— Platinum and allied metals: Mineral Resources for 1917, pt. 1, pp. 11–13, 17–21, 1917.

HORTON, F. W., Platinum and allied metals: Mineral Resources for 1905, pp. 423–432, 1906.

KEMP, J. F., The geological relations and distribution of platinum and associated metals: Bull. 193, 95 pp., 1902.

——— Platinum in the Rambler mine, Wyo.: Mineral Resources for 1902, pp. 244–250, 1904.

KNOPF, ADOLPH, A gold-platinum-palladium lode in southern Nevada: Bull. 620, pp. 1–18, 1916.

LINDGREN, WALDEMAR, Platinum and allied metals: Mineral Resources for 1911, pt. 1, pp. 991–1001, 1912.

SMITH, G. O., Our mineral reserves: Bull. 599, pp. 29–30, 1914.

PORTLAND CEMENT.

ADAMS, G. I., HAWORTH, ERASMUS, and CRANE, W. R., Economic geology of the Iola quadrangle, Kans.: Bull. 238, pp. 63–69, 1904.

BALL, S. H., Portland cement materials in eastern Wyoming: Bull. 315, pp. 232–244, 1907.

BASSLER, R. S., Cement materials of the Valley of Virginia: Bull. 260, pp. 531–544, 1905.

BASTIN, E. S., Clays of the Penobscot Bay region, Maine: Bull. 285, pp. 428–429, 1906.

BURCHARD, E. F., Portland cement materials near Dubuque, Iowa: Bull. 315, pp. 225–231, 1907.

——— Concrete materials produced in the Chicago district [Ill.-Wis.]: Bull. 340, pp. 383–410, 1908.

——— Structural materials available in the vicinity of Minneapolis, Minn.: Bull. 430, pp. 280–291, 1910.

——— Structural materials available in the vicinity of Austin, Tex.: Bull. 430, pp. 292–316, 1910.

——— Cement: Mineral Resources for 1910, pt. 2, pp. 485-532, 1911.

BUTTS, CHARLES, Ganister in Blair County, Pa.: Bull. 380, pp. 337–342, 1909.

CATLETT, CHARLES, Cement resources of the Valley of Virginia: Bull. 225, pp. 457–461, 1904.

CLAPP, F. G., Limestones of southwestern Pennsylvania: Bull. 249, pp. 27–29, 41–43, 1905.

CRIDER, A. F., Cement resources of northeast Mississippi: Bull. 260, pp. 510–521, 1905.

——— Geology and mineral resources of Mississippi: Bull. 283, pp. 71–84, 1906.

CUMMINGS, URIAH, American rock cement: Twenty-first Ann. Rept., pt. 6 (continued), pp. 410–411, 1901.

Darton, N. H., Geology and water resources of the northern portion of the Black Hills and adjoining regions in South Dakota and Wyoming: Prof. Paper 65, 96 pp., 1909.
——— Structural materials in parts of Oregon and Washington: Bull. 387, pp. 20–28, 1909.
——— Cement materials in Republican Valley, Nebr.: Bull. 430, pp. 381–387, 1910.
Darton, N. H., and Siebenthal, C. E., Geology and mineral resources of the Laramie Basin, Wyo.: Bull. 364, p. 65, 1909.
Duryee, Edward, Cement investigations in Arizona: Bull. 213, pp. 372–380, 1903.
Eckel, E. C., Cement-rock deposits of the Lehigh district [Pa.-N. J.]: Bull. 225, pp. 448–450, 1904.
——— Cement materials and industry of the United States: Bull. 243, 395 pp., 15 pls., 1905.
——— The American cement industry: Bull. 260, pp. 496–505, 1905.
——— Portland cement resources of New York: Bull. 260, pp. 522–530, 1905.
——— Cement resources of the Cumberland Gap district, Tenn.-Va.: Bull. 285, pp. 374–376, 1906.
——— Portland cement materials of the United States, with contributions by E. F. Burchard and others: Bull. 522, 401 pp., 19 pls., 1913.
Fenneman, N. M., Geology and mineral resources of the St. Louis quadrangle, Mo.-Ill.: Bull. 438, pp. 55–56, 1911.
Haworth, Erasmus, and Schrader, F. C., Portland cement resources of the Independence quadrangle, Kans.: Bull. 260, pp. 506–509, 1905.
Humphrey, R. L., and Jordan, William, Jr., Portland cement mortars and their constituent materials, results of tests made at the structural-materials testing laboratories, Forest Park, St. Louis, Mo.: Bull. 331, 130 pp., 1908.
Landes, Henry, Cement resources of Washington: Bull. 285, pp. 377–383, 1906.
Lippincott, J. B., Manufacture of Portland cement in southern California: Water-Supply Paper 60, pp. 135–137, 1902.
Martin, G. C., The Niobrara limestone of northern Colorado as a possible source of Portland cement material: Bull. 380, pp. 314–326, 1909.
Newberry, S. B., Portland cement: Twenty-first Ann. Rept., pt. 6 (continued), pp. 400–406, 1901.
Pepperberg, L. J., Cement material near Havre, Mont.: Bull. 380, pp. 327–336, 1909.
Richardson, G. B., Portland cement materials near El Paso, Tex.: Bull. 340, pp. 411–414, 1908.
Russell, I. C., The Portland cement industry in Michigan: Twenty-second Ann. Rept., pt. 3, pp. 629–685, 1902.
Schrader, F. C., and Haworth, Erasmus, Economic geology of the Independence quadrangle, Kans.: Bull. 296, pp. 55–57, 1906.
Siebenthal, C. E., Mineral resources of northeastern Oklahoma: Bull. 340, pp. 217–222, 1908.
Smith, E. A., Cement resources of Alabama: Bull. 225, pp. 424–447, 1904.
Smith, G. O., Our mineral reserves: Bull. 599, pp. 30–31, 1914.
Taff, J. A., Chalk of southwestern Arkansas, with notes on its adaptability to the manufacture of hydraulic cements: Twenty-second Ann. Rept., pt. 3, pp. 687–742, 1902.
Udden, J. A., Oolitic limestone industry at Bedford and Bloomington, Ind.: Bull. 430, pp. 335–345, 1910.

POTASH.

Ashley, G. H., Notes on the greensand deposits of the eastern United States: Bull. 660, pp. 27–49, pl. 2, 1918.
Burchard, E. F., Recovery of potash from Portland cement materials: Mineral Resources for 1915, pt. 2, pp. 206–208, 1916.

BUTLER, B. S., Potash in certain copper and gold ores: Bull. 620, pp. 227–236, 1916.

BUTLER, B. S., and GALE, H. S., Alunite, a newly-discovered deposit near Marysvale, Utah: Bull. 511, pp. 1–64, 1912.

DAY, W. C., Potassium salts: Mineral Resources for 1887, pp. 628–649, 1888.

DOLE, R. B., Exploration of salines in Silver Peak Marsh, Nev.: Bull. 530, pp. 341–345, 1913.

GALE, H. S., The search for potash salts in the desert basin region [Nevada]: Bull. 530, pp. 295–312, 1913.

——— Other investigations of saline deposits: Mineral Resources for 1912, pt. 2, pp. 884–904, 1913.

——— Notes on the Quaternary lakes of the Great Basin, with special reference to the deposition of potash and other salines: Bull. 540, pp. 399–406, 1914.

——— Prospecting for potash in Death Valley, Calif.: Bull. 540, pp. 407–415, 1914.

——— Salt, borax, and potash in Saline Valley, Inyo County, Calif.: Bull. 540, pp. 416–421, 1914.

——— Potash tests at Columbus Marsh, Nev.: Bull. 540, pp. 422–427, 1914.

——— Salines in the Owens, Searles, and Panamint basins, southeastern California: Bull. 580, pp. 309, 312, 1915.

——— Potash: Mineral Resources for 1916, pt. 2, pp. 77–108, 1917.

HANCE, J. H., Potash in western saline deposits: Bull. 540, pp. 457–469, 1914.

HICKS, W. B., Evaporation of potash brines: Prof. Paper 95, pp. 65–72, 1916.

——— The composition of muds from Columbus Marsh, Nev.: Prof. Paper 95, pp. 1–11, 1916.

——— Evaporation of brine from Searles Lake, Calif.: Prof. Paper 98, pp. 1–8, 1917.

LARSEN, E. S., Alunite in the San Cristobal quadrangle, Colo.: Bull. 530, pp. 179–183, 1913.

LOUGHLIN, G. F., Recent alunite developments near Marysvale and Beaver, Utah: Bull. 620, pp. 237–270, 1916.

PARDEE, J. T., Geology and mineral deposits of the Colville Indian Reservation, Wash.: Bull. 677, pp. 179–180, 1918.

PHALEN, W. C., Potash salts, their uses and occurrence in the United States: Mineral Resources for 1910, pt. 2, pp. 758–767, 1911.

——— Potash salts, summary for 1911: Mineral Resources for 1911, pp. 889–906, 1912.

——— Potash salts, summary for 1912: Mineral Resources for 1912, pt. 2, pp. 877–884, 1913.

——— The occurrence of potash salts in the bitterns of the eastern United States: Bull. 530, pp. 313–329, 1913.

——— Potash salts, summary for 1913: Mineral Resources for 1913, pt. 2, pp. 85–101, 1914.

——— Potash salts, summary for 1914: Mineral Resources for 1914, pt. 2, pp. 15–33, 1915.

——— Potash salts: Mineral Resources for 1915, pt. 2, pp. 98–131, 1916.

SCHRADER, F. C., Alunite in granite porphyry near Patagonia, Ariz.: Bull. 540, pp. 347–350, 1912.

——— Alunite at Bovard, Nev.: Bull. 540, pp. 351–356, 1912.

SCHULTZ, A. R., and CROSS, WHITMAN, Potash-bearing rocks of the Leucite Hills, Sweetwater County, Wyo.: Bull. 512, 39 pp., 1912.

SMITH, G. O., Our mineral reserves: Bull. 599, pp. 35–36, 1914.

SMITH, G. O., and others, The classification of the public lands: Bull. 537, pp. 134–138, 1913.

WELLS, R. C., Experiments on the extraction of potash from wyomingite: Prof. Paper 98, pp. 37–40, 1917.

QUICKSILVER.

Bancroft, Howland, Notes on the occurrence of cinnabar in central western Arizona: Bull. 430, pp. 151-153,1910.

——— Reconnaissance of the ore deposits in northern Yuma County, Ariz.: Bull. 451, pp. 44-45, 82-84, 1911.

Becker, G. F., Geology of the quicksilver deposits of the Pacific slope, with atlas: Mon. 13, 486 pp., 1888.

——— Summary of the geology of the quicksilver deposits of the Pacific slope: Eighth Ann. Rept., pt. 2, pp. 965-967, 974-985, 1889.

——— Quicksilver ore deposits: Mineral Resources for 1892, pp. 139-162, 1893.

Boutwell, J. M., Quicksilver: Mineral Resources for 1906, pp. 492-495, 1907.

Christy, S. B., Quicksilver reduction at New Almaden, Calif.: Mineral Resources for 1883-84, pp. 503-507, 1885.

Clarke, F. W., The data of geochemistry, 3d ed.: Bull. 616, pp. 664-669, 1916.

Emmons, W. H., The Neglected mine and near-by properties, Durango quadrangle, Colo.: Bull. 260, pp. 121-127, 1905.

——— The enrichment of ore deposits: Bull. 625, pp. 392-398, 1917.

Hillebrand, W. F., and Schaller, W. T., Mercury minerals from Terlingua, Tex.: Bull. 405, pp. 18-172, 1909.

Knopf, Adolph, Some cinnabar deposits in western Nevada: Bull. 620, pp. 59-68, 1916.

Lindgren, W., The gold quartz veins of Nevada City and Grass Valley districts, Calif.: Seventeenth Ann. Rept., pt. 2, p. 119, 1896.

——— The gold belt of the Blue Mountains of Oregon: Twenty-second Ann. Rept., pt. 2, pp. 664, 708, 1901.

McCaskey, H. D., Quicksilver: Mineral resources for 1907, pt. 1, pp. 678-683, 1908.

——— Quicksilver: Mineral Resources for 1908, pt. 1, pp. 685-688, 1909.

——— Quicksilver: Mineral Resources for 1911, pt. 1, pp. 893-916, 1912.

——— Quicksilver: Mineral Resources for 1912, pt. 1, pp. 931-933, 939-944, 1913.

——— Quicksilver: Mineral Resources for 1914, pt. 1, pp. 317-318, 321-322, 1915.

Melville, W. H., Metacinnabarite from New Almaden, Calif.: Bull. 78, pp. 80-83, 1891.

Melville, W. H., and Lindgren, W., Contributions to the mineralogy of the Pacific coast: Bull. 61, pp. 11-30, 1890.

Parker, E. W., Quicksilver: Twenty-first Ann. Rept., pt. 6, pp. 277-280, 1901.

Ransome, F. L., Notes on some mining districts in Humboldt County, Nev.: Bull. 414, pp. 30, 37, 45, 65, 1909.

——— Quicksilver deposits of the Mazatzal Range, Ariz.: Bull, 620, pp. 111-128, 1916.

Smith, G. O., Geol. Atlas, Mount Stuart [Wash.] folio (No. 106), p. 9, 1904.

Smith, P. S., and Maddren, A. G., Quicksilver deposits of the Kuskokwim region: Bull. 622, pp. 274-291, 1915.

Spurr, J. E., Economic geology of the Mercur mining district, Utah: Sixteenth Ann. Rept., pt. 2, pp. 428-429, 1896.

Turner, H. W., and Ransome, F. L., Geol. Atlas, Sonora [Calif.] folio (No. 41), p. 5, 1897.

RARER METALS.

ANTIMONY.

Bastin, E. S., Antimony: Mineral Resources for 1916, pt. 1, pp. 723-724, 727-728, 1918.

Blake, W. P., Antimony: Mineral Resources for 1883-84, pp. 641-649, 1885.

Brooks, A. H., Geologic features of Alaskan metalliferous lodes: Bull. 480, pp. 91-92, 1911.

——— Antimony deposits of Alaska: Bull. 649, 67 pp., 1916.

Emmons, W. H., The enrichment of ore deposits: Bull. 625, pp., 261-263,408-411,1917.

Hess, F. L., The Arkansas antimony deposits: Bull. 340, pp. 241-256, 1908.

KNOPF, ADOLPH, The antimonial silver-lead veins of the Arabia district, Nev.: Bull. 660, pp. 249–255, 1918.
OVERBECK, R. M., Lode deposits near the Nenana coal field [Alaska]: Bull. 662, pp. 357–358, 1917.
RICHARDSON, G. B., Antimony in southern Utah: Bull. 340, pp. 253–256, 1908.
SMITH, G. O., Our mineral reserves: Bull. 599, pp. 27–29, 1914.

ARSENIC.

EMMONS, W. H., The enrichment of ore deposits: Bull. 625, pp. 261–263, 402–407, 1917.
HESS, F. L., The arsenic deposits at Brinton, Va.: Bull. 470, pp. 205–211, 1911.
——— Arsenic: Mineral Resources for 1914, pt. 1, pp. 953–960, 1916.
SMITH, G. O., Our mineral reserves: Bull. 599, p. 29, 1914.
UMPLEBY, J. B., Arsenic: Mineral Resources for 1917, pt. 1, pp. 23–24, 27, 1918.

BISMUTH.

LINDGREN, WALDEMAR, and LOUGHLIN, G. F., Geology and ore deposits of the Tintic mining district, Utah: Prof. Paper 107, pp. 140, 149, 176, 1919.
OVERBECK, R. M., Lode deposits near the Nenana coal field [Alaska]: Bull. 662, p. 356, 1917.
UMPLEBY, J. B., Bismuth: Mineral Resources for 1917, pt. 1, pp. 29–31, 1918.

MOLYBDENUM.

CALKINS, F. C., Molybdenite near Ramona, San Diego County, Calif.: Bull. 640, pp. 73–76, 1917.
EMMONS, W. H., The enrichment of ore deposits: Bull. 625, pp. 424–427, 1917.
HESS, F. L., Some molybdenum deposits of Maine, Utah, and California: Bull. 340, pp. 231–240, 1908.
HILLEBRAND, W. F., Distribution and quantitative occurrence of vanadium and molybdenum in rocks of the United States: Bull. 167, pp. 49–55, 1900.
MOFFIT, F. H., The upper Chitina Valley, Alaska: Bull. 675, p. 79, 1918.
PRATT, J. H., Tungsten, molybdenum, uranium, and vanadium: Twenty-first Ann. Rept., pt. 6, pp. 305–307, 1901.
SCHRADER, F. C., and HILL, J. M., Some occurrences of molybdenite in the Santa Rita and Patagonia mountains, Ariz.: Bull. 430, pp. 154–163, 1910.
SMITH, G. O., A molybdenite deposit in eastern Maine: Bull. 260, pp. 197–199, 1905.

NICKEL.

BANCROFT, HOWLAND, The ore deposits of northeastern Washington: Bull. 550, p. 30, 1914.
BLAKE, W. P., Nickel: Mineral Resources for 1882, pp. 399–420, 1883.
——— Nickel: Mineral Resources for 1883–84, pp. 538–543, 1885.
CALKINS, F. C., An occurrence of nickel ore in San Diego County, Calif.: Bull. 640, pp. 77–82, 1917.
KAY, G. F., Nickel deposits of Nickel Mountain, Oreg.: Bull. 315, pp. 120–127, 1907.
PACKARD, R. L., Genesis of nickel ores: Mineral Resources for 1893, pp. 170–177, 1894.
RANSOME, F. L., Notes on some mining districts in Humboldt County, Nev.: Bull. 414, pp. 12–58 passim, 1909.
SMITH, G. O., Geol. Atlas, Mount Stuart [Wash.] folio (No. 106), p. 9, 1904.
UMPLEBY, J. B., Geology and ore deposits of Lemhi County, Idaho: Bull. 528, pp. 13–72, 1913.

TIN.

Blake, W. P., Tin ores and deposits: Mineral Resources for 1883–84, pp. 592–629, 1885.
Brooks, A. H., An occurrence of stream tin in the York region, Alaska: Mineral Resources for 1900, pp. 267–271, 1901.
——— Stream tin in Alaska: Bull. 213, pp. 92–93, 1903.
——— Geologic features of Alaskan metalliferous lodes: Bull. 480, pp. 88–90, 1911.
Collier, A. J., Tin deposits of the York region, Alaska: Bull. 225, pp. 154–167, 1903.
——— The tin deposits of the York region, Alaska: Bull. 229, 61 pp., 1904.
——— Recent development of Alaskan tin deposits: Bull. 259, pp. 120–127, 1905.
——— Tin ore at Spokane, Wash.: Bull. 340, pp. 295–305, 1908.
Darton, N. H., Geol. Atlas, Sundance [Wyo.-S. Dak.] folio (No. 127), pp. 11–12, 1905.
Eakin, H. M., The Rampart and Hot Springs regions [Alaska]: Bull. 520, pp. 285–286, 1912.
——— Tin mining in Alaska: Bull. 622, pp. 81–94, 1915.
——— Reconnaissance of a part of the Rampart quadrangle, Alaska: Bull. 535, pp. 28–38 passim, 1913.
Emmons, W. H., The enrichment of ore deposits: Bull. 625, pp. 398–402, 1917.
Graton, L. C., The Carolina tin belt: Bull. 260, pp. 188–195, 1905.
——— Reconnaissance of some gold and tin deposits in the southern Appalachians: Bull. 293, 134 pp., 1906.
Hess, F. L., The York tin region [Alaska]: Bull. 284, pp. 145–157, 1906.
——— Tin, tungsten, and tantalum deposits of South Dakota: Bull. 380, pp. 131–149, 1909.
——— Tin: Mineral Resources for 1911, pt. 1, pp. 963–969, 1912.
——— Tin resources of Alaska: Bull. 520, pp. 89–92, 1912.
Hess, F. C., and Graton, L. C., The occurrence and distribution of tin: Bull. 260, pp. 161–187, 1905.
Johnson, B. L., Occurrence of wolframite and cassiterite in the gold placers of Deadwood Creek, Birch Creek district [Alaska]: Bull. 442, pp. 246–250, 1909.
Keith, Arthur, and Sterrett, D. B., Tin resources of the Kings Mountain district, N. C. and S. C.: Bull. 660, pp. 123–146, pl. 4, 1918.
Knopf, Adolph, The Seward Peninsula [Alaska] tin deposits: Bull. 345, pp. 251–267, 1908.
——— Geology of the Seward Peninsula tin deposits, Alaska: Bull. 358, 72 pp., 9 pls., 1908.
Mertie, J. B., and Harrington, G. L., Mineral Resources of the Ruby-Kuskokwim region [Alaska]: Bull. 642, pp. 238–263 passim, 1916.
——— Tin: Mineral Resources for 1916, pt. 1, pp. 618–619, 1918.
——— Tin: Mineral Resources for 1917, pt. 1, pp. 63–66, 1918.
——— Tin ore in northern Lander County, Nev.: Bull. 640, pp. 125–138, 1916.
Pratt, J. H., Carolina tin belt: Mineral Resources for 1903, pp. 337–344, 1904.
Richardson, G. B., Tin in the Franklin Mountains, Tex.: Bull. 285, pp. 146–149, 1906.
——— Geol. Atlas, El Paso [Tex.] folio (No. 166), pp. 9–10, 1909.
Schaller, W. T., Cassiterite in San Diego County, Calif.: Bull. 620, pp. 351–354, 1916.
Smith, G. O., Our mineral reserves: Bull. 599, pp. 24–25, 1914.
Ulke, T., Occurrence of tin ore in North Carolina and Virginia: Mineral Resources for 1893, pp. 178–182, 1894.
Umpleby, J. B., Geology and ore deposits of Lemhi County, Idaho: Bull. 528, pp. 74–76, 1913.
Weed, W. H., The El Paso tin deposits [Texas]: Bull. 178, 15 pp., 1901.
——— Tin deposits at El Paso, Tex.: Bull. 213, pp. 99–102, 1903.
Anonymous, Tin: Mineral Resources for 1888, pp. 148–156, 1889.

TUNGSTEN.

BANCROFT, H., Notes on tungsten deposits near Deer Park, Wash.: Bull. 430, pp. 214–216, 1910.

——— The ore deposits of northeastern Washington: Bull. 550, pp. 29–30, 1914.

BASTIN, E. S., and HILL, J. M., Economic geology of Gilpin County, Colo.: Bull. 620, pp. 310–311, 1916.

——— Economic geology of Gilpin County and adjacent parts of Clear Creek and Boulder counties, Colo.: Prof. Paper 94, pp. 126–151 passim, 1917.

EMMONS, W. H., The enrichment of ore deposits: Bull. 625, pp. 427–432, 1917.

GARRISON, F. L., Alloys of iron and tungsten: Sixteenth Ann. Rept., pt. 3, pp. 615–623, 1895.

HESS, F. L., Note on a tungsten-bearing vein near Raymond, Calif.: Bull. 340, p. 271, 1908.

——— Minerals of the rare-earth metals at Baringer Hill, Llano County, Tex.: Bull. 340, pp. 286–294, 1908.

——— Tin, tungsten, and tantalum deposits of South Dakota: Bull. 380, pp. 149–157; 1909.

——— Note on a wolframite deposit in the Whetstone Mountains, Ariz.: Bull. 380, pp. 164–165, 1909.

——— Tungsten, nickel, cobalt, etc.: Mineral Resources for 1908, pt. 1, pp. 721–726, 728–731, 1909.

——— Tungsten: Mineral Resources for 1912, pt. 1, pp. 987–994, 1914.

——— Tungsten minerals and deposits: Bull. 652, 85 pp., 25 pls., 1917.

HESS, F. L., and SCHALLER, W. T., Colorado ferberite and the wolframite series: Bull. 583, 75 pp., 1914.

HILL, J. M., Note on the occurrence of tungsten minerals near Calabasas, Ariz.: Bull, 430, pp. 164–166, 1910.

HOBBS, W. H., The old tungsten mine at Trumbull, Conn.: Twenty-second Ann. Rept., pt. 2, pp. 7–22, 1901.

——— Tungsten mining at Trumbull, Conn.: Bull. 213, p. 98, 1903.

JOHNSON, B. L., Occurrence of wolframite and cassiterite in the gold placers of Deadwood Creek, Birch Creek district [Alaska]: Bull. 442, pp. 246–250, 1910.

KNOPF, ADOLPH, Tungsten deposits of northwestern Inyo County, Calif.: Bull. 640, pp. 229–249, 1917.

——— A geologic reconnaissance of the Inyo Range and the eastern slope of the southern Sierra Nevada, Calif.: Prof. Paper 110, p. 124, 1918.

PRATT, J. H., Tungsten: Mineral Resources for 1900, pp. 257–258, 1901.

——— Tungsten, molybdenum, uranium, and vanadium: Twenty-first Ann. Rept., pt. 6, pp. 299–305, 1901.

UMPLEBY, J. B., Geology and ore deposits of Lemhi County, Idaho: Bull. 528, pp. 14–74, 1913.

WEEKS, F. B., An occurrence of tungsten ore in eastern Nevada: Twenty-first Ann. Rept., pt. 6, pp. 319–320, 1901.

——— Tungsten deposits in the Snake Range, White Pine County, eastern Nevada: Bull. 340, pp. 263–270, 1908.

VANADIUM.

BASTIN, E. S., Geology of the pitchblende ores of Colorado: Prof. Paper 90, pp. 1–5, 1914.

BASTIN, E. S., and HILL, J. M., Economic geology of Gilpin County and adjacent parts of Clear Creek and Boulder counties, Colo.: Prof. Paper 94, pp. 121–125, 1917.

BOUTWELL, J. M., Vanadium and uranium in southeastern Utah: Bull. 260, pp. 200–210, 1905.

EMMONS, W. H., The enrichment of ore deposits: Bull. 625, pp. 411–417, 1917.

GALE, H. S., Carnotite in Rio Blanco County, Colo.: Bull. 315, pp. 110–117, pl. 3, 1907.
——— Carnotite and associated minerals in western Routt County, Colo.: Bull. 340, pp. 257–262, 1908.
HESS, F. L., Notes on the vanadium deposits near Placerville, Colo.: Bull. 530, pp. 142–156, 1913.
——— Vanadium in the Sierra de los Caballos, N. Mex.: Bull. 530, pp. 157–160, 1913.
——— Carnotite near Green River, Utah: Bull. 530, pp. 161–164, 1913.
——— Uranium and vanadium: Mineral Resources for 1912, pt. 1, pp. 1003–1035, 1913.
HILLEBRAND, W. F., Distribution and quantitative occurrence of vanadium and molybdenum in rocks of the United States: Bull. 167, pp. 49–55, 1900.
HILLEBRAND, W. F., and RANSOME, F. L., On carnotite and associated vanadiferous minerals in western Colorado: Bull. 262, pp. 9–31, 1905.
WHERRY, E. T., Carnotite near Mauch Chunk, Pa.: Bull. 580, pp. 147–151, 1914.

SALT, BROMINE, AND CALCIUM CHLORIDE.

BREGER, C. L., The salt resources of the Idaho-Wyoming border, with notes on the geology: Bull. 430, pp. 555–569, 1910.
CAMPBELL, M. R., Geol. Atlas, Charleston [W. Va.] folio (No. 72), p. 6, 1901.
CHATARD, T. M., Salt-making processes in the United States: Seventh Ann. Rept., pp. 491–535, 1888.
DARTON, N. H., Zuni salt deposits, New Mexico: Bull. 260, pp. 565–566, 1905.
DOLE, R. B., Exploration of salines in Silver Peak Marsh, Nev.: Bull. 530, pp. 330-341, 1913.
ECKEL, E. C., Salt and gypsum deposits of southwestern Virginia: Bull. 213, pp. 406–416, 1903.
——— Salt industry of Utah and California: Bull. 225, pp. 488–495, 1904.
GALE, H. S., Other investigations of saline deposits: Mineral Resources for 1912, pt. 2, pp. 884–905, 1913.
——— Notes on the Quaternary lakes of the Great Basin, with special reference to the deposition of potash and other salines: Bull. 540, pp. 399-406, 1914.
——— Salt, borax, and potash in Saline Valley, Inyo County, Calif.: Bull. 540, pp. 416–421, 1914.
——— The origin of colemanite deposits: Prof. Paper 85, pp. 3–9, 1914.
——— Salines in the Owens, Searles, and Panamint basins, southeastern California: Bull. 580, pp. 251–323, pls. 5–7, 1914.
HANCE, J. H., Potash in western saline deposits: Bull. 540, pp. 457–469, 1914.
HICKS, W. B., Evaporation of brine from Searles Lake .Calif.: Prof. Paper 98, pp. 1–8, 1917.
HILGARD, E. W., The salines of Louisiana: Mineral Resources for 1882, pp. 554–565, 1883.
HOPKINS, O. B., The Palestine salt dome, Anderson County, Tex.: Bull. 661, pp. 253–269, 1918.
KINDLE, E. M., Salt resources of the Watkins Glen district, N. Y.: Bull. 260, pp. 567–572, 1905.
PACKARD, R. L., Natural sodium salts: Mineral Resources for 1893, pp. 728–734, 1894.
PARKER, E. W., Salt: Eighteenth Ann. Rept., pt. 5, pp. 1288–1313, 1897.
——— Salt: Twenty-first Ann. Rept., pt. 6 (continued), pp. 531–554, 1901.
PHALEN, W. C., Salt and bromine: Mineral Resources for 1909, pt. 2, pp. 664-672, 1911.
——— Salt and bromine: Mineral resources for 1912, pt. 2, pp. 913–923, 1913.
——— Salt resources of the United States: Bull. 669, 284 pp., 17 pls., 1918.
RICHARDSON, G. B., Salt, gypsum, and petroleum in trans-Pecos Texas: Bull. 260, pp. 578–580, pl. 4, 1905.

Stone, R. W., Salt, bromine, and calcium chloride: Mineral Resources for 1916, pt. 2, pp. 220–221, 1917.

——— Salt, bromine, and calcium chloride: Mineral Resources for 1917, pt. 2, pp. 177-181, 1918.

Stose, G. W., Geology of the salt and gypsum deposits of southwestern Virginia: Bull. 530, pp. 232-255, 1913.

SAND AND GRAVEL.

Burchard, E. F., The requirements of sand and limestone for glass making: Bull. 285, pp. 452–458, 1905.

——— Glass sand of the middle Mississippi basin: Bull. 285, pp. 459–472, 1905.

——— Glass-sand industry of Indiana, Kentucky, and Ohio: Bull. 315, pp. 361–381, 1906.

——— Concrete materials produced in the Chicago district: Bull. 340, pp. 398–410, 1908.

——— Structural materials in vicinity of Austin, Tex.: Bull. 430, pp. 305-306, 1910.

——— Structural materials available in the vicinity of Minneapolis, Minn.: Bull. 430, pp. 285–287, 1910.

——— Glass sand, other sand, and gravel: Mineral Resources for 1911, pt. 2, pp. 593–623, 1912.

Campbell, M. R., Geol. Atlas, Latrobe [Pa.] folio (No. 110), p. 15, 1904.

Coons, A. T., Glass sand: Mineral Resources for 1902, pp. 1008-1013, 1903.

Humphrey, R. L., and Jordan, William, jr., Portland cement mortars and their constituent materials: Bull. 331, pp. 42–124, 1908.

Miser, H. D., and Purdue, A. H., Gravel deposits of Caddo Gap and De Queen quadrangles, Ark.: Bull. 690, pp. 15–30, pls. 1–3, 1918.

Shaw, E. W., Gravel and sand in the Pittsburgh district, Pa.: Bull. 430, pp. 388–399, 1910.

Stone, R. W., Sand and gravel: Mineral Resources for 1915, pt. 2, pp. 222–225, 1916.

——— Sand and gravel: Mineral Resources for 1916, pt. 2, pp. 334–339, 1917.

Stose, G. W., The glass-sand industry in eastern West Virginia: Bull. 285, pp. 473–475, 1905.

Stose, G. W., and Swartz, C. K., Geol. Atlas, Pawpaw-Hancock [W. Va.-Md.-Pa.] folio (No. 179), pp. 21, 23, 1912.

Weeks, J. D., Glass materials: Mineral Resources for 1883–84, pp. 958–977, 1885.

SULPHUR.

Adams, G. I., The Rabbit Hole sulphur mines, near Humboldt House, Nev.: Bull. 225, pp. 497–500, 1904.

Davis, H. J., Pyrites: Mineral Resources for 1885, pp. 501–517, 1886.

Eckel, E. C., Gold and pyrite deposits of the Dahlonega district, Ga.: Bull. 213, pp. 57–63, 1903.

——— Pyrite deposits of the eastern Adirondacks, N. Y.: Bull. 260, pp. 587–588, 1905.

Hess, F. L., A sulphur deposit in the San Rafael Canyon, Utah: Bull. 530, pp. 347–349, 1913.

Hewett, D. F., Sulphur deposits of Sunlight Basin, Wyo.: Bull. 530, pp. 350–362, pl. 7, 1913.

——— Sulphur deposits in Park County, Wyo.: Bull. 540, pp. 477–480, 1914.

Larsen, E. S., and Hunter, J. F., Two sulphur deposits in Mineral County, Colo.: Bull. 530, pp. 363–369, 1913.

Lee, W. T., The Cove Creek sulphur beds, Utah: Bull. 315, pp. 485–489, 1907.

Phalen, W. C., Sulphur and pyrite: Mineral Resources for 1907, pt. 2, pp. 674–676, 1908.

Phalen, W. C., Sulphur and pyrite: Mineral Resources for 1909, pt. 2, pp. 686–688, 1911.
——— Sulphur and pyrite; map showing location of salt, sulphur, and pyrite deposits of the United States: Mineral Resources for 1910, pt. 2 (in pocket), 1911.
——— Sulphur, pyrite, and sulphuric acid: Mineral Resources for 1912, pt. 2, pp. 934–952, 1913.
——— Sulphur, pyrite, and sulphuric acid: Mineral Resources for 1913, pt. 2, pp. 25–44, 1914.
Ransome, F. L., Geology and ore deposits of Goldfield, Nev.: Prof. Paper 66, pp. 109–110, 113–114, 1909.
Richards, R. W., and Bridges, J. H., Sulphur deposits near Soda Springs, Idaho: Bull. 470, pp. 499–504, 1911.
Richardson, G. B., Native sulphur in El Paso County, Tex.: Bull. 260, pp. 589–592, 1905.
Smith, G. O., Our mineral reserves: Bull. 599, p. 40, 1914.
Smith, P. S., Sulphur, pyrite, and sulphuric acid: Mineral Resources for 1916, pt. 2, pp. 405–418, 1918.
——— Sulphur, pyrites, and sulphuric acid: Mineral Resources for 1917, pt. 2, pp. 22–24, 1918.
Woodruff, E. G., Sulphur deposits at Cody, Wyo.: Bull. 340, pp. 451–456, pl. 6, 1908.
——— Sulphur deposits near Thermopolis, Wyo.: Bull. 380, pp. 373–380, 1909.

TALC AND SOAPSTONE.

Diller, J. S., Talc and soapstone: Mineral Resources for 1908, pt. 2, pp. 869–870, 873–877, 1909.
——— Talc and soapstone: Mineral Resources for 1909, pt. 2, pp. 919–922, 1911.
——— Talc and soapstone: Mineral Resources for 1912, pt. 2, pp. 1143–1145, 1913.
——— Talc and soapstone: Mineral Resources for 1916, pt. 2, pp. 27–28, 1917.
——— Talc and soapstone: Mineral Resources for 1917, pt. 2, pp. 83–84, 1918.
Keith, Arthur, Talc deposits of North Carolina: Bull. 213, pp. 433–438, 1903.
——— Geol. Atlas, Asheville [N. C.-Tenn.] folio (No. 116), pp. 8–9, 1904.
——— Geol. Atlas, Mount Mitchell [N. C.-Tenn.] folio (No. 124), p. 7, 1905.
——— Geol. Atlas, Nantahala [N. C.-Tenn.] folio (No. 143), pp. 8–9, 1906.
——— Geol. Atlas, Pisgah [N. C.-S. C.] folio (No. 147), pp. 6–7, 1907.
Parker, E. W., Soapstone: Twenty-first Ann. Rept., pt. 6, pp. 413–418, 1901.

ZINC.

Adams, G. I., Zinc and lead deposits of northern Arkansas: Bull. 213, pp. 187–213, 1903.
Adams, G. I., and others, Zinc and lead deposits of northern Arkansas: Prof. Paper 24, pp. 14–40, 1904.
Bain, H. F., Lead and zinc deposits of Illinois: Bull. 225, pp. 202–207, 1904.
——— Lead and zinc resources of the United States: Bull. 260, pp. 262–273, 1905.
——— Zinc and lead in northwestern Illinois: Bull. 246, pp. 1–56 passim, 1905.
——— A Nevada zinc deposit: Bull. 285, pp. 166–169, 1906.
——— Zinc and lead ores in 1905: Mineral Resources for 1905, pp. 379–388, 1906.
——— Zinc and lead deposits of the upper Mississippi Valley: Bull. 294, pp. 71–148 passim, 1906.
Bain, H. F., Van Hise, C. R., and Adams, G. I., Preliminary report on the lead and zinc deposits of the Ozark region [Mo.]: Twenty-second Ann. Rept., pt. 2, pp. 111–116, 1901.
Bancroft, Howland, Ore deposits of northeastern Washington: Bull. 550, pp. 26–27, 44–51, 115–116, 1914.

BOUTWELL, J. M., Ore deposits of Bingham, Utah: Bull. 213, pp. 115, 118, 1903.
——— Economic geology of the Bingham mining district, Utah: Prof. Paper 38, pp. 112–280 passim, 376–377, 1905.
——— Geology and ore deposits of the Park City district, Utah: Prof. Paper 77, pp. 33–35, 108–109, 1912.
BUTLER, B. S., Geology and ore deposits of the San Francisco and adjacent districts, Utah: Prof. Paper 80, pp. 117–171 passim, 1913.
BUTLER, B. S., and HEIKES, V. C., Notes on the Promontory district, Utah: Bull. 640, pp. 8–9, 1917.
CLERC, F. L., The mining and metallurgy of lead and zinc in the United States: Mineral Resources for 1882, pp. 358–374, 1883.
ELLIS, E. E., Zinc and lead mines near Dodgeville, Wis.: Bull. 260, pp. 311–315, 1905.
EMMONS, W. H., Some ore deposits in Maine and the Milan mine, N. H.: Bull. 432, pp. 20–43, 1910.
——— The enrichment of sulphide ores: Bull. 529, pp. 141–143, 1913.
——— The enrichment of ore deposits: Bull. 625, pp. 377–390, 1917.
GRANT, U. S., Zinc and lead deposits of southwestern Wisconsin: Bull. 260, pp. 304–310, 1905.
HILL, J. M., Mining districts of the western United States: Bull. 507, pp. 1–43, 1912.
——— Zinc-lead ore dressing at Goodsprings, Nev.: Mineral Resources for 1912, pt. 1, pp. 787–789, 1913.
IRVING, J. D., and BANCROFT, HOWLAND, Geology and ore deposits in the vicinity of Lake City, Colo.: Bull. 478, p. 57, 1911.
KEITH, ARTHUR, Recent zinc mining in east Tennessee: Bull. 225, pp. 208–213, 1904.
KNOPF, ADOLPH, Mineral resources of the Inyo and White mountains, Calif.: Bull. 540, pp. 95–108, 1914.
——— A geologic reconnaissance of the Inyo Range and the eastern slope of the southern Sierra Nevada, Calif.: Prof. Paper 110, pp. 106–118, 1918.
LINDGREN, WALDEMAR, The gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho: Twentieth Ann. Rept., pt. 3, pp. 211, 405–406, 1900.
——— The Tres Hermanas mining district, N. Mex.: Bull. 380, pp. 124–128, 1909.
——— Resources of the United States in gold, silver, copper, lead, and zinc: Bull. 394, pp. 114–118, 150–157, pl. 11, 1909.
LINDGREN, WALDEMAR, and LOUGHLIN, G. F., Geology and ore deposits of the Tintic mining district, Utah: Prof. Paper 107, pp. 140, 148–149, 170–177, 225–226, 1919.
LINDGREN, WALDEMAR, GRATON, L. C., and GORDON, C. H., The ore deposits of New Mexico: Prof. Paper 68, pp. 20–24, 47, 49, 55, 1910.
LOUGHLIN, G. F., Zinc carbonate and related copper carbonate ores at Ophir, Utah. Bull. 690, pp. 1–14, 1918.
——— The oxidized zinc ores of Leadville, Colo.: Bull. 681, 87 pp., 8 pls., 1918.
MACDONALD, D. F., Economic features of northern Idaho and northwestern Montana: Bull. 285, pp. 45–50, 1906.
PEPPERBERG, L. J., Notes on the mineral deposits of the Bearpaw Mountains, Mont.: Bull. 430, pp. 137–143, 1910.
RANSOME, F. L., Report on the economic geology of the Silverton quadrangle, Colo.: Bull. 182, pp. 80–81, 100, 1901.
——— The ore deposits of the Rico Mountains, Colo.: Twenty-second Ann. Rept., pt. 2, pp. 249–250, 1901.
——— Geology and ore deposits of the Coeur d'Alene district, Idaho: Prof. Paper 62, pp. 83, 91–92, 140, 1908.
——— Geology and ore deposits of the Breckenridge district, Colo.: Prof. Paper 75, pp. 21, 168–169, 1911.
SCHRADER, F. C., The mineral deposits of the Cerbat Range, Black Mountains, and Grand Wash Cliffs, Mohave County, Ariz.: Bull. 397, pp. 43–219, 1909.

SIEBENTHAL, C. E., Mineral resources of northeastern Oklahoma: Bull. 340, pp. 187–210, pl. 2, 1908.

——— Origin of the zinc and lead deposits of the Joplin region, Mo., Kans., and Okla.: Bull. 606, 274 pp., 1915.

——— Zinc: Mineral Resources for 1914, pt. 1, pp. 877–895, 1916.

——— Zinc: Mineral Resources for 1915, pt. 1, pp. 859–949, 1917.

SMITH, G. O., Note on a mineral prospect in Maine: Bull. 315, pp. 118–119, 1907.

——— Our mineral reserves: Bull. 599, pp. 17–22, 1914.

SMITH, W. S. T., Lead and zinc deposits of the Joplin district, Mo.-Kans.: Bull. 213, pp. 197–204, 1903.

——— Lead, zinc, and fluorspar deposits of western Kentucky: Prof. Paper 36, pp. 115–146, 1905.

SMITH, W. S. T., and SIEBENTHAL, C. E., Geol. Atlas, Joplin district [Mo.-Kans.] folio (No. 148), p. 12, 1907.

SPENCER, A. C., Geology and ore deposits of Ely, Nev.: Prof. Paper 96, pp. 71, 100–104, 1917.

SPENCER, A. C., SALISBURY, R. D., and KÜMMEL, H. B., Geol. Atlas, Franklin Furnace [N. J.] folio (No. 161), pp. 7–8, 1908.

SPURR, J. E., Geology of the Aspen mining district, Colo.: Mon. 31, pp. 224–226, 1898.

——— The ore deposits of Monte Cristo, Wash.: Twenty-second Ann. Rept., pt. 2, pp. 836–864, 1901.

——— Descriptive geology of Nevada south of the fortieth parallel and adjacent portions of California: Bull. 208, pp. 54, 97, 213, 1903.

SPURR, J. E., and GARREY, G. H., Preliminary report on the ore deposits of the Georgetown mining district, Colo.: Bull. 260, pp. 107–120, 1905.

——— Economic geology of the Georgetown quadrangle, Colo.: Prof. Paper 63, pp. 23, 136–147, 244, 1908.

TOWER, G. W., jr., and SMITH, G. O., Geology and mining industry of the Tintic district, Utah: Nineteenth Ann. Rept., pt. 3, pp. 686–707, 1899.

ULRICH, E. O., and SMITH, W. S. T., Lead, zinc, and fluorspar deposits of western Kentucky: Bull. 213, pp. 206–213, 1903.

——— Lead, zinc, and fluorspar deposits of western Kentucky: Prof. Paper 36, pp. 15–21, 115–178, 1905.

UMPLEBY, J. B., Geology and ore deposits of Lemhi County, Idaho: Bull. 528, p. 111, 1913.

——— Geology and ore deposits of the Mackay region, Idaho: Prof. Paper 97, pp. 10, 86–98, 1917.

WEED, W. H., and BARRELL, JOSEPH, Geology and ore deposits of the Elkhorn mining district, Jefferson County, Mont.: Twenty-second Ann. Rept., pt. 2, pp. 459–464, 474–476, 1901.

WEED, W. H., and PIRSSON, L. V., Geology of the Castle Mountain mining district, Mont.: Bull. 139, pp. 151, 158–160, 1896.

WOLFF, J. E., Zinc and manganese deposits of Franklin Furnace, N. J.: Bull. 213, pp. 214–217, 1903.

O