CEMENT

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By Story B. Ladd.

Hydraulic cements are of three kinds, Portland or artificial cement, natural-rock cement, and Pozzuolana or slag cement. The last-named class does not fall within the scope of the mining census, nor does the manufacture of any kind of cement, except as it is associated with the mining or quarrying of the raw material; hence the statistics presented in Tables 1 and 8 include only the Portland and natural-rock cement made by establishments mining or quarrying the raw material, at least in part. In cases where the raw material was manufactured into cement by the operator of the mine or quarry, the statistics include the manufacture, as well as the mining and quarrying, of the raw material; and where a part of the raw material was mined or quarried and a part purchased, the complete mining and manufacturing statistics are included, because it was impossible to differentiate the statistics chargeable to the purchased material from those pertaining to material mined or quarried.

The comparative statistics from 1850 to 1902, inclusive, are shown in Table 1.

Table 1.—*Comparative summary: 1850 to 1902.*

	1902	1889	1880	1870[1]	1860[1]	1850[1]
Number of mines or quarries	101	(2)	28	(2)	(2)	(2)
Number of operators	93	(2)	(2)	[3]45	[3]14	[3]35
Salaried officials, clerks, etc.:						
Number	913	(2)	(2)	(2)	(2)	(2)
Salaries	$1,087,514	(2)	(2)	(2)	(2)	(2)
Wage-earners:						
Average number	13,041	(2)	2,102	1,632	740	407
Wages	$6,328,852	(2)	$750,367	$631,993	$206,460	$117,924
Contract work	$10,627	(2)	(2)	(2)	(2)	(2)
Miscellaneous expenses	$1,665,520	(2)	(2)	(2)	(2)	(2)
Cost of supplies and materials	$9,098,226	(2)	$500,463	$773,192	$262,920	$238,157
Product:[4]						
Quantity, barrels	24,655,360	[5]7,000,000	2,072,943	(2)	(2)	(2)
Value	$24,268,338	[5]$5,000,000	$1,852,707	$2,033,893	$767,080	$509,110

[1] From Census Report on Manufactures.
[2] Not reported.
[3] Establishments.
[4] The United States Geological Survey reports 25,753,504 barrels, valued at $25,366,380, which includes all manufactured cement. The Census reports only the product of operators mining, quarrying, or excavating raw material.
[5] Estimate in Eleventh Census Report on Mining Industries, page xv.

The growth of the industry has been very great. The increase of production in 1889 over 1880 was nearly 240 per cent, and the increase in 1902 over 1889 was more than 250 per cent.

In 1902 there were 93 operators, of whom 4 were individuals, 6 were firms, and 83 were incorporated companies, as shown by Table 8, a detailed summary of the statistics. Of the individual operators, 3 were located in New York and 1 in Minnesota, and of the firms, 4 were in New York and 1 each in Maryland and Minnesota. The 83 corporations, constituting 89.2 per cent of the operators and owning 91 establishments, or 90.1 per cent of the whole, produced 98.3 per cent of the product. All of the Portland cement was made by incorporated companies. The statistics for the present census are the most complete that have ever been published. At the Eleventh Census no statistics in regard to cement production were reported in connection with the mining census, except the estimated quantity and value of the cement product, 7,000,000 barrels, having a total value of $5,000,000.

Capital stock of incorporated companies.—Table 2 presents in detail the capitalization of incorporated companies.

The state of Pennsylvania led both in number of companies and in capital invested, as represented by the par value of stocks and bonds issued, reporting 39.1 per cent of the entire par value. New York, with 13 corporations, ranked second in number of companies, and Michigan was third, with 10 companies. One company operating in Ohio also owns and operates a plant in Indiana; 1 company operating in Indiana also owns and operates a plant in Kentucky; 1 company in Pennsylvania operates 2 plants in that state, and another company in Pennsylvania operates 3 plants in that state and 1 in Indiana. In the case of 1 limestone company in Michigan and 1 in New York, producing cement as a minor product, the capitalization is reported in connection with the limestone industry. Two companies—1 in Alabama and 1 in Michigan—did not report capitalization; the former was an English corporation, and the latter was engaged extensively in other business, cement being but a small part of the total.

TABLE 2.—CAPITALIZATION OF INCORPORATED COMPANIES: 1902.

	United States.	Illinois.	Indiana.	Maryland.	Michigan.	New York.	Ohio.	Pennsylvania.	Virginia.	All other states.
Number of incorporated companies	83	6	7	3	10	13	7	14	3	[1]20
Number reporting capitalization	81	6	7	3	9	13	7	14	3	[2]19
Capital stock and bonds issued	$55,649,870	$2,056,500	$1,401,800	$381,200	$8,910,720	$8,424,200	$2,156,100	$21,765,350	$1,474,000	$9,080,000
Capital stock:										
Total authorized—										
Number of shares	1,098,893	33,700	19,780	3,500	565,000	70,850	28,000	265,000	11,000	102,063
Par value	$50,556,500	$1,520,000	$1,238,000	$300,000	$7,450,000	$7,245,000	$2,480,000	$19,650,000	$1,050,000	$9,623,500
Total issued—										
Number of shares	995,345	33,700	19,362	3,422	496,492	63,772	22,881	252,277	10,640	92,799
Par value	$46,932,170	$1,520,000	$1,216,800	$292,200	$6,764,920	$6,537,200	$1,968,100	$18,852,350	$1,032,000	$8,748,600
Dividends paid	$1,209,667	$26,231	$52,634	.....	$137,069	$70,000	$95,586	$556,020	.....	$272,127
Common—										
Authorized—										
Number of shares	965,193	33,700	19,780	3,500	515,000	44,100	23,000	222,800	11,000	92,313
Par value	$42,003,000	$1,520,000	$1,238,000	$300,000	$6,950,000	$4,570,000	$1,980,000	$15,695,000	$1,050,000	$8,700,000
Issued—										
Number of shares	865,222	33,700	19,362	3,422	446,492	37,022	18,581	211,954	10,640	84,049
Par value	$38,653,520	$1,520,000	$1,216,800	$292,200	$6,264,920	$3,862,200	$1,538,100	$15,053,700	$1,032,000	$7,873,600
Dividends paid	$958,367	$26,231	$52,634	.....	$102,069	$52,000	$71,586	$381,720	.....	$272,127
Preferred—										
Authorized—										
Number of shares	133,700	.....	.....	.....	50,000	26,750	5,000	42,200	.....	9,750
Par value	$8,553,500	.....	.....	.....	$500,000	$2,675,000	$500,000	$3,955,000	.....	$923,500
Issued—										
Number of shares	130,123	.....	.....	.....	50,000	26,750	4,300	40,323	.....	8,750
Par value	$8,278,650	.....	.....	.....	$500,000	$2,675,000	$430,000	$3,798,650	.....	$875,000
Dividends paid	$251,300	.....	.....	.....	$35,000	$18,000	$24,000	$174,300	.....	.....
Bonds:										
Authorized—										
Number	15,217	3,130	200	190	2,760	2,117	380	4,270	730	1,440
Par value	$9,578,400	$565,000	$200,000	$95,000	$2,215,000	$2,097,000	$380,000	$3,250,000	$445,000	$331,400
Issued—										
Number	14,159	3,073	185	178	2,642	1,907	188	3,846	700	1,440
Par value	$8,717,700	$536,500	$185,000	$89,000	$2,145,800	$1,887,000	$188,000	$2,913,000	$442,000	$331,400
Interest paid	$316,962	$32,190	$9,250	$5,340	$62,126	$41,076	$6,360	$149,650	$10,000	$970
Assessments levied	$35,396	.....	.....	.....	.....	$35,396	.....	.....	.....	.....

[1] Includes companies distributed as follows: Alabama, 1; California, 2; Colorado, 1; Georgia, 2; Kansas, 2; Kentucky, 1; Missouri, 1; New Jersey, 2; North Dakota, 1; South Dakota, 1; Texas, 2; Utah, 1; West Virginia, 1; Wisconsin, 2.

[2] Includes companies distributed as follows: California, 2; Colorado, 1; Georgia, 2; Kansas, 2; Kentucky, 1; Missouri, 1; New Jersey, 2; North Dakota, 1; South Dakota, 1; Texas, 2; Utah, 1; West Virginia, 1; Wisconsin, 2.

Dividends to the aggregate amount of $1,209,667 were reported as paid by 31 companies, of which 6 were located in New York, 6 in Pennsylvania, 4 in Indiana, 3 in Michigan, 2 each in Illinois, Kansas, Ohio, and New Jersey, and 1 each in Colorado, South Dakota, Utah, and Wisconsin. Dividends to the amount of $251,300 were paid on preferred stock of a total par value of $3,605,000, by 3 companies in Pennsylvania, 2 in New York, and 1 each in Michigan and Ohio; and dividends aggregating $958,367 were paid on common stock of a total par value of $11,441,910, by 4 companies in Indiana, 4 in New York, 3 in Pennsylvania, 2 each in Illinois, Kansas, Michigan, New Jersey and Ohio, and 1 each in Colorado, South Dakota, Utah, and Wisconsin. The dividends paid averaged 7 per cent on the preferred stock and 8.4 per cent on the common stock of the companies reporting them.

The sum of $35,396 was paid in assessments to 2 companies in New York. Outstanding bonds aggregating $8,717,700 were reported by 34 companies; but the interest reported, amounting to $316,962, was paid by only 25 companies on bonds of a par value of $6,081,700, distributed as follows: Pennsylvania, $2,813,000; Michigan, $1,145,800; New York, $787,000; Illinois, $536,500; Virginia, $400,000; Indiana, $185,000; Ohio, $106,000; Maryland, $89,000; and "all other states," $19,400.

Employees and wages.—Of the $7,416,366 paid for salaries and wages, $1,087,514 was paid to 913 salaried officials, clerks, etc., and $6,328,852 to 13,041 wage-earners. The salaried employees comprised 148 general officers, who received $347,132, an average salary of $2,346; 426 superintendents, managers, foremen, surveyors, etc., who received $491,671, an average of $1,154; and 339 clerks, who received $248,711, an average of $734. Of the 13,041 wage-earners 2,092 were engineers, firemen, and other mechanics, who received $1,324,121; 3,251 were miners or quarrymen and miners' helpers, who received $1,440,029; and 111 were boys under 16 years of age, who received $23,499; the 7,587 other wage-earners received $3,541,203.

Mining below ground was reported in the case of 14 mines or quarries, of which 5 were located in New York, 3 in Maryland, and 1 each in Illinois, Indiana, North Dakota, Ohio, Virginia, and Wisconsin. Boys under 16 years of age were employed in 22 mines—6 in Pennsylvania, 5 in New York, 2 each in Kansas and Virginia, and 1 each in Alabama, California, Georgia, Indiana, Maryland, Texas, and Utah. Of these mines, only 1, located in the state of New York, reports the employment of boys underground.

The variation in the numbers of wage-earners employed at different seasons of the year is shown in Table 8, which gives the average number of men and boys employed during each month. Taking the industry as a whole, the minimum number was employed in February and the maximum in September, with a steady increase from February to September, followed by a slight falling off in the fall and early winter. The increase in the number of wage-earners for December over the number employed in January, 35 per cent, reflects the growth of the industry, which was most marked in Michigan, Illinois, and Indiana.

In addition to asking for the average number of employees and the total amount paid as wages, the schedule called for the number of wage-earners employed at specified daily rates of pay. These statistics are shown in the following table:

TABLE 3.—DISTRIBUTION OF WAGE-EARNERS ACCORDING TO DAILY RATES OF PAY, BY OCCUPATIONS: 1902.

RATE PER DAY (DOLLARS).	ALL OCCUPATIONS.		ENGINEERS.		FIREMEN.		MACHINISTS, BLACKSMITHS, CARPENTERS, AND OTHER MECHANICS.		MINERS AND QUARRYMEN.		BOYS UNDER 16 YEARS.		ALL OTHER WAGE-EARNERS.	
	Average number.	Per cent of total.	Average number.	Per cent of total.	Average number.	Per cent of total.	Average number.	Per cent of total.	Average number.	Per cent of total.	Average number.	Per cent of total.	Average number.	Per cent of total.
Total	13,041	100.0	337	100.0	338	100.0	1,417	100.0	3,031	100.0	111	100.0	7,807	100.0
Less than 0.50	37	0.3									37	33.3		
0.50 to 0.74	20	0.2							2	(1)	15	13.5	3	(1)
0.75 to 0.99	192	1.5			2	0.6	1	0.1	54	1.8	38	34.3	97	1.3
1.00 to 1.24	1,099	8.4	9	2.7	31	9.2	70	4.9	350	11.5	19	17.1	620	7.9
1.25 to 1.49	3,849	29.5	39	11.6	27	8.0	120	8.5	1,166	38.5	1	0.9	2,496	32.0
1.50 to 1.74	4,107	31.5	17	5.0	67	19.8	251	17.7	895	29.5	1	0.9	2,876	36.8
1.75 to 1.99	1,632	12.5	26	7.7	86	25.4	214	15.1	327	10.8			979	12.5
2.00 to 2.24	933	7.2	98	29.1	87	25.7	300	21.2	169	5.6			279	3.6
2.25 to 2.49	427	3.3	58	17.2	24	7.1	119	8.4	26	0.9			200	2.6
2.50 to 2.74	433	3.3	42	12.5	5	1.5	190	13.4	32	1.1			164	2.1
2.75 to 2.99	103	0.8	15	4.4	1	0.3	49	3.4	8	0.3			30	0.4
3.00 to 3.24	125	1.0	26	7.7	8	2.4	58	4.1	2	(1)			31	0.4
3.25 to 3.49	47	0.4	3	0.9			32	2.2					12	0.2
3.50 to 3.74	19	0.1					5	0.4					14	0.2
3.75 to 3.99	7	(1)	3	0.9			2	0.1					2	(1)
4.00 to 4.24	7	(1)	1	0.3			5	0.4					1	(1)
4.25 and over	4	(1)					1	0.1					3	(1)

[1] Less than one-tenth of 1 per cent.

Three-fifths of all wage-earners were paid from $1.25 to $1.74 per day, 29.5 per cent receiving from $1.25 to $1.49, and 31.5 per cent from $1.50 to $1.74; of those at lower rates, 8.4 per cent received from $1 to $1.24 and 2 per cent less than $1; while of those at higher rates 12.5 per cent received from $1.75 to $1.99, and 16.1 per cent $2 and over.

Of the total number of wage-earners 3,031, or 23.2 per cent, were miners or quarrymen; of this class, 2,061, or 68 per cent, received from $1.25 to $1.74 per day. Of the 3,031 miners or quarrymen distributed in Table 3 according to daily rates of pay, there were 449, 14.8 per cent of the total number, for whom rates had to be computed, because they were paid by the ton or cubic yard. The total amount paid them was $215,796.

Contract mining or quarrying was reported for 11 mines or quarries, located 3 each in New York, Ohio, and Pennsylvania, and 1 each in California, Michigan, and Utah, at rates ranging from $0.18 to $0.40 per ton, except in the case of 1 mine in Ohio, where the rate was $1.25 per gross ton. In addition, 1 establishment in Michigan reported the excavation of marl by contract at $0.055 per cubic yard.

Contract work.—Contract work for tunneling, shaft sinking, boring test holes, etc., was reported by 3 establishments, 1 each in Kansas, Kentucky, and New York. The number of men so employed was 34, and the amount paid for such contract work was $10,627.

Supplies, materials, and miscellaneous expenses.—The total expenditure reported for supplies and materials was $9,098,226. As cement is marketed in barrels or bags, the containers constitute quite an item of expense. The total amount reported for miscellaneous expenses was $1,665,520; of this amount, $52,905 was paid by 14 operators—4 in Pennsylvania, 3 in Ohio, and 1 each in Kansas, Maryland, Minnesota, New York, Texas, Utah, and Wisconsin—for royalties and rent of mine or quarry and mining plant, and $1,612,615 was expended for rent of offices, taxes, insurance, interest, and other sundries.

Mechanical power.—The primary power employed in the cement industry aggregated 114,092 horsepower, of which 110,650 was owned and 3,442 rented, the latter being electric power. Of the power owned, 93.8 per cent was steampower. Electric motors were employed in the industry of a total capacity of 17,420 horsepower.

Production.—The total production of hydraulic cement by establishments mining or quarrying raw material in whole or in part, was 24,655,360 barrels, valued at $24,268,338. Pennsylvania was the largest producer, reporting 9,360,802 barrels, or 38 per cent of the entire product; this state and New York together reported 57.2 per cent of the total production. Pennsylvania produced 51.3 per cent of the Portland cement, and New York 44.9 per cent of the natural-rock cement.

Of the 101 mines or quarries covered by Tables 1 and 8, 54 manufactured Portland cement only and 37 natural-rock cement only, while 10 produced both Portland and natural-rock cement. The 54 establishments manufacturing only Portland cement produced 14,115,121 barrels, at an aggregate expense of $12,655,189; nearly 90 per cent of this product was reported by 40 establishments in the states of Illinois, Indiana, Michigan, New Jersey, New York, Ohio, and Pennsylvania. Among the 54 mines or quarries producing Portland cement exclusively there were 13—7 in Michigan, 3 in New York, 2 in Ohio, and 1 in Indiana—which reported the manufacture, in the aggregate, of 1,981,415 barrels of Portland cement from marl. The marl mined or excavated by these establishments was reported in some

cases in cubic yards and in other cases in tons, the quantity reported being 723,385 cubic yards and 359,277 tons. In Michigan the development of the marl cement industry has been very great; the 7 establishments reporting from that state excavated 655,902 cubic yards and 20,000 tons of marl, and produced 1,167,052 barrels of cement.

The 37 establishments manufacturing only natural-rock cement produced, in the aggregate, 6,954,704 barrels of cement at an aggregate expense of $2,732,514.

The entire hydraulic cement production of the United States for 1902, including cement manufactured by companies not mining or quarrying any portion of the material, is shown in Table 4.

TABLE 4.—CEMENT PRODUCTION: 1902.

CEMENT MANUFACTURED BY—	Number of establishments.	Number of operators.	PRODUCTION.							
			Total.		Portland cement.		Natural-rock cement.		Pozzuolana or slag cement.	
			Barrels.	Value.	Barrels.	Value.	Barrels.	Value.	Barrels.	Value.
All establishments	112	102	25,753,504	$25,366,380	17,230,644	$20,864,078	8,044,305	$4,076,630	478,555	$425,672
Establishments mining or quarrying raw material in whole or in part	101	93	24,655,360	24,268,338	16,691,055	20,231,708	7,964,305	4,036,630	.....	.....
Establishments not mining or quarrying raw material[1]	11	9	1,098,144	1,098,042	539,589	632,370	80,000	40,000	478,555	425,672

[1] Not included in mining census reports, but included in "Mineral Resources of the United States," published by the United States Geological Survey.

Of the 25,753,504 barrels of hydraulic cement of all kinds manufactured in 1902, 66.9 per cent was Portland cement, 31.2 per cent was natural-rock cement, and 1.9 per cent was Pozzuolana, or slag cement. Of the entire production, 24,655,360 barrels, or 95.7 per cent, was the product of establishments that mined or quarried raw material, at least in part; this product included 96.9 per cent of all Portland cement and 99 per cent of all the natural-rock cement manufactured, but none of the Pozzuolana or slag cement. Cement was manufactured from purchased material by 11 establishments. Of these, 4 establishments—1 each in Colorado, Illinois, Ohio, and Pennsylvania—manufactured Portland cement; 1 establishment in Kansas manufactured natural-rock cement; and 6 establishments—2 in Alabama and 1 each in Illinois, Maryland, New Jersey, and Ohio—made Pozzuolana, or slag cement. The 2 establishments in Alabama manufacturing slag cement were owned by the same company, and 1 company in Illinois manufactured both Portland and slag cement.

The growth of the entire cement industry from 1890 to 1902, inclusive, and the imports during the same period are shown in the following table:

TABLE 5.—CEMENT PRODUCTION AND IMPORTS: 1890 TO 1902.

[Compiled from reports of United States Geological Survey, "Mineral Resources of the United States."]

YEAR.	PRODUCTION.								Imports (barrels).
	Total.		Portland cement.		Natural rock cement.		Pozzuolana, or slag cement.		
	Barrels.	Value.	Barrels.	Value.	Barrels.	Value.	Barrels.	Value.	
1890	7,776,616	$6,380,625	335,500	$704,050	7,441,116	$5,676,575	.....	.....	1,940,186
1891	8,222,792	6,671,437	454,813	967,429	7,767,979	5,704,008	.....	.....	2,988,313
1892	8,758,621	7,152,750	547,440	1,153,600	8,211,181	6,999,150	.....	.....	2,440,654
1893	8,002,467	6,262,846	590,652	1,158,138	7,411,815	5,104,708	.....	.....	2,674,149
1894	8,362,245	5,030,081	798,767	1,383,473	7,563,488	3,646,608	.....	.....	2,638,107
1895	8,731,401	5,482,254	990,324	1,586,830	7,741,077	3,895,424	.....	.....	2,997,395
1896	9,513,473	6,473,213	1,543,023	2,424,011	7,970,450	4,049,202	.....	.....	2,989,597
1897	10,989,463	8,178,283	2,677,775	4,315,891	8,311,688	3,862,392	.....	.....	2,090,924
1898	[1]12,111,208	9,859,501	3,692,284	5,970,773	8,418,924	3,888,728	([2])	([2])	2,013,818
1899	15,520,445	12,889,142	5,652,266	8,074,371	9,868,179	4,814,771	([2])	([2])	2,108,388
1900	17,231,150	13,283,581	8,482,020	9,280,525	8,383,519	3,728,848	365,611	$274,208	2,386,683
1901	20,068,737	15,786,789	12,711,225	12,532,360	7,084,823	3,056,278	272,689	198,151	939,330
1902	[3]25,753,504	25,366,380	17,230,644	20,864,078	8,044,305	4,076,630	478,555	425,672	1,994,789

[1] Not including 233,000 barrels of Pozzuolana, or slag cement, the value of which was not reported.
[2] Not reported.
[3] Includes cement manufactured by the 11 establishments not mining or quarrying any raw material, and therefore not included in mining census reports. (See Table 4.)

The production of cement has steadily increased throughout the period covered by this table, except in 1892–93. The natural-rock cement production, however, shows no real growth; it reached its maximum in 1899, and the production in 1902, though greater than that in 1901, is less than that in 1892. On the other hand, the growth in the production of Portland cement has been very great; from 1892 to 1902 the rate of yearly growth averaged 40 per cent, ranging from 7.9 per cent in 1892–93 to 73.5 per cent in 1896–97, so that

during the decade the output increased more than thirty-fold. Portland cement outstripped natural rock cement in value in 1897, and in quantity in 1900. The imports reached a maximum in 1895; since that year there has been, on the whole, a considerable decrease, the imports for 1902 exceeding very slightly those for 1890. Since 1897, except in 1900, the annual imports have been below the average of the imports for the entire period of thirteen years, and in 1902 they were approximately on a par with the imports for 1890.

Kilns.—The kiln equipment of the 101 establishments included in Table 8 comprised 584 vertical and 451 rotary kilns. As a rule, natural cement rock is calcined in vertical and Portland cement mixtures in rotary kilns; but 3 establishments in New York and 1 in South Dakota reported the use of 47 vertical kilns in the manufacture of Portland cement, and 1 establishment in Minnesota used 5 rotary kilns for natural-rock cement.

Nonproducers.—There were 51 nonproducing cement establishments, of which 20 were new plants in course of erection. The number, distribution, and character of ownership of these establishments are shown in the following table:

TABLE 6.—*Nonproducing mines or quarries: 1902.*

	United States.	Indiana.	Michigan.	New Jersey.	New York.	Ohio.	Pennsylvania.	Virginia.	All other states and territories.[1]
Number of mines or quarries	51	[2]10	9	3	6	3	5	3	12
New mines or quarries	20	.....	8	2	1	1	4	.....	[3]4
Number of operators	49	9	9	3	6	3	5	[4]2	12

[1] Includes 1 mine or quarry each in Arkansas, California, Colorado, Florida, Georgia, Illinois, Kentucky, Massachusetts, Nebraska, New Mexico, Texas, and West Virginia.
[2] One owned by an active establishment operating in Kentucky.
[3] Includes 1 mine or quarry each in Arkansas, California, Georgia, and New Mexico.
[4] One individual owns 2 idle mines or quarries.

Of the 51 nonproducing establishments, 31—10 in Indiana, 5 in New York, 3 in Virginia, 2 in Ohio, and 1 each in Colorado, Florida, Illinois, Kentucky, Massachusetts, Michigan, Nebraska, New Jersey, Pennsylvania, Texas, and West Virginia—were properly "idle establishments." The other 20—8 in Michigan, 4 in Pennsylvania, 2 in New Jersey, and 1 each in Arkansas, California, Georgia, New Mexico, New York, and Ohio—were in course of erection during the year.

There were 44 incorporated companies which reported ownership of nonproducing mines or quarries—24 owning idle establishments and 20 owning the 20 establishments in course of construction. Capitalization was reported by 16 of these companies, distributed as follows: Companies owning idle establishments, 6 in Indiana and 1 each in Michigan, New York, and Ohio, or a total of 9; companies owning establishments in course of construction (or "new establishments"), 3 in Michigan and 1 each in Arkansas, New Jersey, New York, and Pennsylvania, or a total of 7. The statistics of the capitalization of the nonproducing companies reporting capitalization are shown in Table 7.

TABLE 7.—*Capitalization of nonproducing incorporated companies: 1902.*

	Total.	Idle companies.	New companies owning plants in course of construction.
Number of incorporated companies	44	24	20
Number reporting capitalization	16	9	7
Capital stock and bonds issued	$17,517,700	$2,356,700	$15,191,000
Capital stock:			
Total authorized—			
Number of shares	545,389	55,889	489,500
Par value	$27,638,900	$5,588,900	$22,050,000
Total issued—			
Number of shares	403,167	23,567	379,600
Par value	$17,147,700	$2,356,700	$14,791,000
Dividends paid	$12,362	$12,362	.....
Common—			
Authorized—			
Number of shares	437,389	35,889	401,500
Par value	$19,238,900	$3,588,900	$15,650,000
Issued—			
Number of shares	356,667	18,567	338,100
Par value	$14,072,700	$1,856,700	$12,216,000
Dividends paid	$12,362	$12,362	.....
Preferred—			
Authorized—			
Number of shares	108,000	20,000	88,000
Par value	$8,400,000	$2,000,000	$6,400,000
Issued—			
Number of shares	46,500	5,000	41,500
Par value	$3,075,000	$500,000	$2,575,000
Bonds:			
Authorized—			
Number	1,100	.....	1,100
Par value	$630,000	.....	$630,000
Issued—			
Number	400	.....	400
Par value	$400,000	.....	$400,000

If the 7 new companies reporting capitalization are representative of all such companies, there has been a marked increase in the average capitalization per company. The 7 new companies reporting capitalization show a total par value of stocks and bonds issued amounting to $15,191,000, or an average of $2,170,143, as compared with an average of $670,480 for the 83 active companies for which capitalization is reported in Table 2.

The following statistics were reported by 9 of the 51 nonproducing mines or quarries—5 in Indiana and 1 each in New Jersey, New York, Michigan, and Pennsylvania:

Summary, nonproducing mines or quarries: 1902.

Number of mines or quarries reporting	9
Salaried officials, clerks, etc.:	
Number	43
Salaries	$52,333
Wage-earners:	
Average number	340
Wages	$214,617
Miscellaneous expenses	$36,647
Cost of supplies and materials	$3,086
Total horsepower	11,187

Of the salaries, $14,380 was paid to 9 general officers; $28,513 to 16 superintendents, managers, foremen, surveyors, etc.; and $9,440 to 18 clerks. Of the wages, $155,849 was paid to 229 engineers, firemen, and other mechanics; $17,458 to 28 miners or quarrymen—26 above ground and 2 below ground—and $41,310 to 83 other wage-earners. The miscellaneous expenses repre-

sented the rent of offices, taxes, insurance, interest, and other sundries. The mechanical power was furnished by 26 steam engines, of 8,835 horsepower; 2 gas or gasoline engines, of 12 horsepower; 1 water wheel of 40 horsepower; and 78 electric motors, of 2,300 horsepower.

A detailed summary showing the statistics for cement during 1902 is given in Table 8.

DESCRIPTIVE.

Hydraulic cements are of three general classes:[1]

(1) Portland cement, a compound consisting essentially of lime, silica, and alumina, produced by mixing intimately some form of calcium carbonate with the necessary proportion of clay, calcining the mixture at a high heat, and grinding the resulting clinker to a fine powder. A mixture of Portland cement and sand ground to an extremely fine powder is called sand cement.

(2) Natural-rock cement, produced by calcining at a comparatively low heat a natural product—such as argillaceous limestone—possessing in its composition lime and clay in proportions adapted to form a hydraulic cement, and usually containing also a considerable proportion of magnesia.

(3) Pozzuolana, or slag cement, produced by mixing with slacked lime a natural volcanic scoria or granulated blast furnace slag of suitable composition.

The chemical constituents of the three general classes of hydraulic cement are approximately as follows:

CONSTITUENTS.	Portland.	Natural rock.	Slag.
Lime (per cent)	58.0 to 67.0	32.3 to 53.5	36.0 to 55.0
Silica (per cent)	20.3 to 26.1	21.1 to 35.4	18.0 to 28.0
Alumina (per cent)	5.2 to 10.6	6.3 to 14.5	9.0 to 19.0
Iron oxide (per cent)	2.1 to 5.3	1.7 to 5.1	0.3 to 2.8
Magnesia (per cent)	0.3 to 2.3	1.4 to 20.9	0.5 to 7.0
Sulphuric acid (per cent)	0.3 to 1.8	.....	0.2 to 2.7

The process of formation and hardening of the cement is similar in all cases, depending chiefly upon the formation of calcium silicates, which become hydrated and crystallize under the action of water. If it were possible to find a natural product containing lime and clay in the right proportions, a cement of the correct Portland standard could be made from it by the simple operations of calcining and grinding; but a variation of 1 per cent from the correct standard greatly reduces the value of the cement. Most of the argillaceous limestones of the United States contain a high proportion of magnesia and an excess of clay. If burned at the high temperature necessary to produce Portland cement, they fuse to a slag which does not possess hydraulic properties; but when burned at a heat only sufficient to drive off the carbonic acid, they yield a soft yellow clinker, which, when ground, gives the natural-rock cement of commerce.

[1] "Portland Cement," by S. B. Newberry, in "The Cement Industry," reprinted from the Engineering Record, has been largely drawn from.

PORTLAND CEMENT.

Ingredients used.—The necessary materials for Portland cement are calcium carbonate (usually in the form of limestone, chalk, or marl) and clay or shale. The relative proportions of the two depend upon their varying composition.

The calcium carbonate should be as pure as possible, except for the presence of clay. Magnesia is always present to some extent, and though it is generally agreed that up to 3.5 per cent it is harmless, a large percentage is objectionable. Calcium sulphate in excess of about 2.5 per cent is also objectionable, unless a decided oxidizing flame be maintained in burning, as it is liable to be reduced to the sulphide. Both magnesia and calcium sulphate are considered especially objectionable in cements that are to be exposed to the action of sea water.

In England a comparatively soft chalk is generally used; in Germany, chalk or limestone. In the United States a large part of the Portland cement is made from the slate-like limestone of the Lehigh valley region. This material contains rather more clay than is required for a correct mixture, so that a small proportion of pure limestone—usually from 10 to 20 per cent—is added. In New York, Ohio, and Michigan marl, a soft fresh-water deposit similar to chalk, is generally employed. Pure limestone is used in a few cases only.

The chemical composition of certain typical forms of calcium carbonate used in the manufacture of Portland cement is shown in the following table:

CONSTITUENTS.	CHALK.	CEMENT ROCK.			MARL.	
	England (Reed).	Lasalle, Ill.	Phillipsburg, N. J.	Siegfried, Pa.	Sandusky, Ohio.	Syracuse, Ind.
Calcium carbonate	98.57	88.16	70.10	68.91	91.77	88.49
Silica	0.64	8.20	15.05	17.32	0.22	1.78
Alumina	0.16	1.00	9.02	7.07	1.22	0.91
Iron oxide	0.08	0.30	1.27	2.01	0.40	0.30
Magnesium carbonate	0.38	1.78	3.96	4.28	0.53	2.71
Calcium sulphate	.....	.....	.....	.....	3.49	1.58

The clay should be highly siliceous, low in magnesia and sulphates, and free from sand. For the best results the proportion of silica should be at least three times as great as that of iron oxide and alumina combined. Highly aluminous clays give a fusible clinker and quick-setting cement, while clays containing more than 5 per cent of iron oxide give a dark-colored cement.

The following table presents an analysis of a few typical clays used in Portland cement manufacture:

CONSTITUENTS.	Medway, England.	Harper, Ohio.	Sandusky, Ohio.	Lasalle, Ill.
Silica	70.56	51.50	65.41	54.30
Alumina	14.52	13.23	16.54	19.33
Iron oxide	3.06	3.30	6.06	5.57
Lime	4.43	11.52	2.22	3.29
Magnesia	.....	3.45	1.88	2.57
Carbonic acid	3.48	12.85	.....	.....
Alkalies	3.95	.....	.....	.....

The small proportion of alkalies present in ordinary clays exerts but little influence and hence is not generally determined.

Mixing.—The method of mixing originally practiced in England was the wet process, in which the materials were ground and mixed in water, and settled in reservoirs, and the "slurry" dried previous to burning. In the dry process, now largely used, the materials are ground and mixed in the dry state. Marl and clay are mixed in a plastic condition. Rock crushers, followed by buhrstones, emery mills, tube mills, or Griffin mills, are generally used for the dry grinding of raw material, and pans with edge runners, followed by tube mills, for wet grinding. The chemical composition of the mixture is constantly tested, and the percentage of calcium carbonate is kept within the 0.5 per cent of that found to be correct for the materials used.

Burning.—Over 95 per cent of the Portland cement is now burned in rotary kilns. The rotary kiln consists of a slightly inclined cylinder, lined with fire brick, turning at the rate of one revolution in from one to three minutes. Fuel oil was formerly used as a source of heat, but powdered coal is now generally employed. The cement material is fed in continuously at the upper end in the form of dry powder, or, in the case of marl and clay, as liquid mud. Descending gradually, it parts with its water, if any, in the upper third of the kiln, becomes heated to redness, loses its carbonic acid, forms small rounded balls which reach a nearly white heat in the lower third of the kiln, and finally issues at the lower end as well-burned black clinker in grains about pea size.

When the burning is done in vertical kilns, the dry powder is first moistened and molded into bricks, which are again dried before being fed into the kiln. According to Le Chatelier, the following changes take place during the burning: At a red heat the combined water is expelled from the clay; at a somewhat higher temperature the calcium carbonate is decomposed into carbonic acid gas, which escapes, and lime, which immediately enters into combination with the silica and alumina of the clay, producing calcium silicates and aluminates. At first, fusible glasses, rich in silica, are formed; by combining with more lime, these gradually become more and more basic, until at last the tricalcium silicate is produced. The iron and alumina also remain in combination with lime as an alumino-ferrite.

The proper degree of burning is indicated by the formation of a dense green-black clinker. Underburned clinker is brownish and soft, while overburned clinker is fused and slag-like; long-continued burning or an excess of clay causes the clinker to "dust" or fall to powder on cooling, the resulting powder showing little or no hydraulic properties. Underburned cement is apt to be quick-setting and to expand and crack in hardening; on the other hand, overburned cement is usually slow in setting and hardening, though it may show excellent tests at long periods. Cement properly proportioned, mixed, and burned does not begin to set in less than two hours after mixing with water, but after the setting begins it hardens rapidly and shows a steady gain in strength, especially when tested with sand, up to several years. It is an almost universal practice to add from 1 to 2 per cent of ground gypsum to retard the setting.

Grinding.—Portland cement clinker was formerly ground with buhrstones and bolted through revolving screens. At present the Griffin mill or the German ball mill, followed by the tube mill, is generally used. A degree of fineness, such that 92 to 93 per cent will pass through a No. 100 sieve, is generally attained. Finer grinding can easily be accomplished, if necessary, but is rarely demanded. There is, of course, a point beyond which it is not economical to carry the fine pulverizing of cement, since the same result can be accomplished by using slightly richer mixtures.

The numerous tests shown in the reports of Government and private engineers warrant the claim that no Portland cement made in any foreign country equals the product of the leading American factories.

NATURAL ROCK CEMENT.

Of the natural rock cement produced in the United States in 1902, about 45 per cent came from the state of New York; about 22 per cent from Kentucky and Indiana, within a radius of 15 miles of Louisville, Ky.; and the remainder largely from Pennsylvania and Illinois.

Rosendale cements.—Of the natural-rock cements the Rosendale cements, manufactured in Ulster county, N. Y., from a natural cement rock known as the Tentaculite or water-lime deposit of the lower Helderberg group of the New York Geological Survey, are typical.

The Rosendale cement industry is the oldest manufacture of hydraulic cement in the country. Dating from 1832, the industry has been developed conservatively and successfully.

The rock deposit is a magnesian limestone, of which two different beds, known respectively as the "light" rock and the "dark" rock, are quarried for cement. Both rocks are hard, compact, and close-grained, the light rock having a steely-blue color, and the dark a duller and deader color and a more shaly appearance. Apparently the light rock contains the more lime and the dark the more clay. After calcination the light rock is yellow, and the dark a redder or dark sienna color. It is a tradition that no good cement can be made without a mixture of the two.

At Binnewater, Ulster county, the depth of the dark-rock deposit, which is the lower bed of cement rock, is about 18 feet, that of the light rock is from 10 to 17 feet, and that of the unworked strata between the two is about 12 feet. The dip varies, but is generally about 45 degrees. The general mining scheme is to run slopes

to a depth of about 40 feet, following the dip of the dark rock, and then to start breasts or headings in both directions along the strike. When the headings have been run out to daylight, to property limits, or to the limit of economical working, the slope is run down 40 or 50 feet farther and new headings started. The rock is loaded on cars which are run through the headings to the foot of the slope and hauled up by cable. To get at the light-rock deposit, which is overhead, horizontal gangways are cut from the gangways in the dark rock through the hanging wall into the bed of light rock, and headings are then started in it in both directions, just as in the lower formation, the cars being run through the connecting gangways and up the slope.

In chemical composition the Rosendale cements are remarkable for the high proportion of magnesia they contain; it varies considerably in different Rosendale brands, but the following analysis is typical of these cements as a class:[1]

Silica	24.30
Alumina	7.22
Ferric oxide	5.06
Lime	33.70
Magnesia	20.94
Volatile matter and undetermined	8.78
Total	100.00

The condition of the successful use of magnesian limestones is light burning, and this requirement is carefully observed in all the Rosendale factories.

Louisville cements.—The so-called Louisville cements are next in importance to the Rosendale product. An extensive deposit of limestone occurs at Louisville, Ky., forming the bed of the Ohio river, and causing the falls and rapids at that place. The first manufacture of Louisville cement began alongside of and in conjunction with the construction of the Louisville and Portland Canal around the Louisville falls. The largest plant in the Louisville district is at Speeds, Indiana.

The cement rock is of the same geological horizon as the water-lime deposits of New York, Pennsylvania, and Wisconsin. A general analysis is about as follows:

Silica and insoluble matter	15.0
Alumina and iron oxide	6.0
Calcium carbonate	61.0
Calcium sulphate	5.0
Magnesium carbonate	10.0
Water, alkalies, etc	3.0
Total	100.0

It is worked both in open quarries and by mining. At the Speeds mills the rock is graded into three sizes, at a breaker provided with screens, the fine stuff calcining more readily than heavy rock.

Manufacturing process.—For calcining natural cement rock, vertical kilns are generally used. They are operated continuously, by drawing from the bottom and charging at the top. In charging, a layer of rock is thrown in, then a thin layer of anthracite pea coal, then another layer of rock, etc. The fuel consumption is low, the output of cement per ton of coal being quite high. At Binnewater the kilns are 28 feet high and 10 feet in diameter, with a daily capacity of from 90 to 100 barrels of marketable cement stone, after discarding all hard-burned clinker and sorting out the underburned clinker for recalcination. At the Speeds mills they are 30 feet high and have an inside diameter of 13 feet, with a daily capacity up to 250 barrels.

The calcined rock is run through crackers and then screened; the coarse rock is next ground in mills, but the finest grades pass directly to the barrel packers. The product is packed as it is ground—nearly all of it in barrels.

SLAG CEMENT.

The manufacture of hydraulic cement from furnace slag has reached considerable proportions abroad, but in this country it is comparatively a new industry. It is not directly within the scope of the mining census, but it is noticed briefly because it utilizes a waste product of mined material.

It is only occasionally that ores and fluxes employed in blast furnaces will produce slag suitable for cement, furnace slags as ordinarily produced by casting and slow cooling being devoid of hydraulic properties. Slag to be used for cement is run off from the furnaces and dropped in a molten state into a trough through which is forced a large stream of cold water; the slag solidifies in vesicles or bubbles, which break up into thin, shell-like pieces. The best grade of such slag has a delicate blue color, and though hard is thin and porous, and hence is readily crushed. The rest of the process is extremely simple, consisting in drying the slag, mixing it with the proper proportions of slaked lime, and then grinding the mixture to a fine powder. The Maryland Cement Company utilizes the slag from the blast furnaces of the Maryland Steel Company, at Sparrow Point, Md. Cuban iron ores are largely used in these furnaces with oyster shells as flux.

INVENTIONS.

Invention has played an important part in the development of the cement industry, both in the improvement of cement compositions and processes of manufacture and in the perfecting of methods and machinery, whereby the cost of manufacture has been greatly reduced and uniformity of product secured. Many of the operators own and control patents for such inventions; a digest of all patents pertaining to processes or compositions employed in the industry—not including patents for apparatus or machines—is attached hereto. The term of a United States patent is seventeen years, so that all patents which have run for that period are public property.

[1] The Cement Industry, page 153.

TABLE 8.—DETAILED SUMMARY: 1902.

	United States.	Illinois.	Indiana.	Maryland.	Michigan.	New York.	Ohio.	Pennsylvania.	Virginia.	All other states.[1]
Number of mines or quarries	101	6	9	4	11	21	7	17	3	23
Number of operators	93	6	7	4	10	20	7	14	3	22
Character of ownership:										
Individual	4					3				1
Firm	6			1		4				1
Incorporated company	83	6	7	3	10	13	7	14	3	20
Salaried officials, clerks, etc.:										
Total number	913	50	65	22	102	141	49	207	43	234
Total salaries	$1,087,514	$59,259	$71,166	$17,227	$131,131	$160,282	$57,838	$250,252	$44,675	$295,684
General officers—										
Number	148	12	10	5	17	21	14	26	6	37
Salaries	$347,132	$26,400	$23,850	$4,916	$43,450	$46,801	$21,600	$73,265	$15,500	$91,350
Superintendents, managers, foremen, surveyors, etc.—										
Number	406	19	24	6	58	59	19	91	20	110
Salaries	$476,661	$20,868	$29,080	$5,376	$68,281	$66,781	$25,703	$108,756	$18,900	$132,966
Foremen, below ground—										
Number	20		1	4		11	1		1	2
Salaries	$15,010		$620	$2,800		$9,025	$700		$375	$1,490
Clerks—										
Number	339	19	30	7	27	50	15	90	16	85
Salaries	$248,711	$11,991	$17,616	$4,135	$19,400	$37,725	$9,835	$68,231	$9,900	$69,878
Wage-earners:										
Aggregate average number	13,041	488	568	170	938	2,459	375	5,376	178	2,489
Aggregate wages	$6,328,852	$261,926	$266,949	$74,677	$535,570	$1,203,313	$227,548	$2,411,652	$83,423	$1,263,794
Above ground—										
Total average number	12,524	484	531	107	938	2,083	366	5,376	163	2,476
Total wages	$6,084,053	$258,676	$253,163	$45,232	$535,570	$1,022,946	$219,962	$2,411,652	$79,423	$1,257,429
Engineers, firemen, and other mechanics—										
Average number	2,092	46	77	15	147	262	39	1,146	39	321
Wages	$1,324,121	$34,879	$45,197	$8,560	$114,955	$163,471	$31,277	$657,587	$29,595	$238,600
Miners or quarrymen—										
Average number	2,766	75	125	6	171	184	52	1,503	56	594
Wages	$1,210,291	$39,647	$53,267	$2,137	$87,802	$89,472	$29,259	$606,253	$21,004	$281,450
Boys under 16 years—										
Average number	109		1	1		32		45	6	24
Wages	$22,530		$231	$200		$8,169		$9,193	$1,297	$3,440
All other wage-earners—										
Average number	7,557	363	328	85	620	1,605	275	2,682	62	1,537
Wages	$3,527,111	$184,150	$154,468	$34,335	$332,813	$761,834	$159,426	$1,138,619	$27,527	$733,939
Below ground—										
Total average number	517	4	37	63		376	9		15	13
Total wages	$244,799	$3,250	$13,786	$29,445		$180,367	$7,586		$4,000	$6,365
Miners—										
Average number	265	4	37	58		130	8		15	13
Wages	$130,638	$3,250	$13,786	$26,445		$69,726	$7,066		$4,000	$6,365
Miners' helpers—										
Average number	220					220				
Wages	$99,100					$99,100				
Boys under 16 years—										
Average number	2					2				
Wages	$969					$969				
All other wage-earners[2]—										
Average number	30			5		24	1			
Wages	$14,092			$3,000		$10,572	$520			
Average number of wage-earners at specified daily rates of pay:										
Engineers—										
$1.00 to $1.24	9							9		
$1.25 to $1.49	39					2		35	1	1
$1.50 to $1.74	17			2		4	1	10		
$1.75 to $1.99	26		1	1		6		14	1	3
$2.00 to $2.24	98	5	11	1	5	15	6	28	3	24
$2.25 to $2.49	58		2	2	6	3		21	1	23
$2.50 to $2.74	42	3	4		6	11	3	8		7
$2.75 to $2.99	15				5	2		2		6
$3.00 to $3.24	26	1			9	2	4	3		7
$3.25 to $3.49	3								2	1
$3.75 to $3.99	3	1			1				1	
$4.00 to $4.24	1	1								
Firemen—										
$0.75 to $0.99	2									2
$1.00 to $1.24	31							28		3
$1.25 to $1.49	27		2	1		2	2	18	1	1
$1.50 to $1.74	67		12	2	5	20		5	9	14
$1.75 to $1.99	86	1			6	17	5	47		10
$2.00 to $2.24	87	11	2	1	2	18	5	29		19
$2.25 to $2.49	24				9	4				11
$2.50 to $2.74	5							1		4
$2.75 to $2.99	1				1					
$3.00 to $3.24	8	1			5					2
Machinists, blacksmiths, carpenters, and other mechanics—										
$0.75 to $0.99	1									1
$1.00 to $1.24	70							66		4
$1.25 to $1.49	120		5	1		4		106		4
$1.50 to $1.74	251	1	10			21		192	8	19
$1.75 to $1.99	214	1	3	1	15	18	2	158		16
$2.00 to $2.24	300		8	1	8	29	2	231	4	17
$2.25 to $2.49	119	9	3	1	18	40		38	4	6
$2.50 to $2.74	190	4	13	1	18	29	6	36		83
$2.75 to $2.99	49	3			12	7		18	2	7
$3.00 to $3.24	58	3	1		14	2	3	23	1	11
$3.25 to $3.49	32	1			1	3		20		7
$3.50 to $3.74	5					2				3
$3.75 to $3.99	2				1					1
$4.00 to $4.24	5					1				4
$4.25 and over	1								1	
Miners or quarrymen—										
$0.50 to $0.74	2		2							
$0.75 to $0.99	54								15	39
$1.00 to $1.24	350		29	6				301	2	12
$1.25 to $1.49	1,166		81	31	1	73	7	763	54	156
$1.50 to $1.74	895	27	42	7	91	121	10	410		187
$1.75 to $1.99	327	45	2	20	63	50	7	19		121
$2.00 to $2.24	169	3	1		15	55	26	2		67
$2.25 to $2.49	26		1			14	2	4		5

[1] Includes operators distributed as follows: Alabama, 1; California, 2; Colorado, 1; Georgia, 2; Kansas, 2; Kentucky, 1 (2 quarries); Minnesota, 2; Missouri, 1; New Jersey, 2; North Dakota, 1; South Dakota, 1; Texas, 2; Utah, 1; West Virginia, 1; Wisconsin, 2.

[2] Includes timbermen and track layers.

TABLE 8.—DETAILED SUMMARY: 1902—Continued.

	United States.	Illinois.	Indiana	Maryland.	Michigan.	New York.	Ohio.	Pennsylvania.	Virginia.	All other states.
Average number of wage-earners at specified daily rates of pay—Continued.										
Miners or quarrymen—Continued.										
$2.50 to $2.74	32	4	4			1		3		20
$2.75 to $2.99	8						8			
$3.00 to $3.24	2				1			1		
Miners' helpers—										
$1.50 to $1.74	220					220				
Timbermen and track layers—										
$1.25 to $1.49	14					7		7		
$1.50 to $1.74	1									1
$1.75 to $1.99	5					1				4
Boys under 16 years—										
Less than $0.50	37							24		13
$0.50 to $0.74	15		1	1		4		1	6	2
$0.75 to $0.99	38					14		20		4
$1.00 to $1.24	19					14				5
$1.25 to $1.49	1					1				
$1.50 to $1.74	1					1				
All other wage-earners—										
$0.50 to $0.74	3		2							1
$0.75 to $0.99	97						3	25		69
$1.00 to $1.24	620		4	12	2	12	3	566	5	16
$1.25 to $1.49	2,482		96	58	23	418	36	1,325	26	500
$1.50 to $1.74	2,655	307	906	8	200	888	59	364	30	593
$1.75 to $1.99	974	13	7	10	338	163	24	135	1	283
$2.00 to $2.24	279	23	6		37	38	77	55		43
$2.25 to $2.49	200	17			1	26	72	63		21
$2.50 to $2.74	164		7	2	5	32	2	113		3
$2.75 to $2.99	30	2			3	13		10		2
$3.00 to $3.24	31	1			5	14		11		
$3.25 to $3.49	12				3	1		7		1
$3.50 to $3.74	14					13		1		
$3.75 to $3.99	2					2				
$4.00 to $4.24	1				1					
$4.25 and over	3				2	1				
Average number of wage-earners employed during each month:										
Men 16 years and over—										
January	10,330	418	327	138	420	1,888	355	4,670	145	1,969
February	10,272	420	294	133	419	1,846	353	4,693	157	1,957
March	10,771	434	413	129	564	1,729	355	4,834	161	2,152
April	12,200	445	447	173	701	2,420	386	5,050	171	2,497
May	13,180	463	475	179	1,051	2,749	386	5,154	176	2,547
June	13,280	492	452	186	1,077	2,775	360	5,171	169	2,598
July	13,479	480	451	187	1,109	2,738	360	5,241	179	2,734
August	14,506	484	665	191	1,179	2,688	361	5,907	189	2,842
September	14,549	485	757	177	1,171	2,725	363	5,963	183	2,725
October	14,349	477	865	180	1,191	2,555	382	5,869	188	2,642
November	14,185	631	840	179	1,191	2,509	417	5,724	184	2,510
December	13,969	627	818	176	1,183	2,478	422	5,696	162	2,407
Boys under 16 years—										
January	96			1		30		37	6	22
February	92					30		34	6	22
March	112		1	1		33		46	6	25
April	123		1	2		35		54	6	25
May	123		2	1		35		54	6	25
June	116		1	1		35		48	6	25
July	115		1	1		35		49	6	23
August	116			1		35		49	6	25
September	117		2	1		35		48	6	25
October	110		2	1		35		41	6	25
November	110		2	1		35		43	6	23
December	102			1		35		37	6	23
Contract work:										
Amount paid	$10,627					$4,450				$6,177
Number of employees	34					4				30
Miscellaneous expenses:										
Total	$1,605,520	$35,621	$53,447	$17,914	$170,477	$310,772	$71,829	$711,782	$31,487	$262,191
Royalties and rent of mine and mining plant	$52,905			$2,201		$11,644	$1,677	$13,448		$23,935
Rent of offices, taxes, insurance, interest, and other sundries	$1,612,615	$35,621	$53,447	$15,713	$170,477	$299,128	$70,152	$698,334	$31,487	$238,256
Cost of supplies and materials	$9,098,226	$185,881	$420,168	$51,879	$704,237	$1,374,640	$231,322	$4,048,508	$91,100	$1,390,491
Product:										
Quantity, barrels	24,655,360	1,058,084	1,879,891	409,200	1,577,006	4,734,147	597,088	9,360,802	284,000	4,755,142
Value	$24,268,338	$769,251	$1,286,228	$150,680	$2,134,396	$3,656,589	$714,551	$10,223,267	$327,659	$5,005,717
Portland cement—										
Quantity, barrels	16,691,055	450,264	536,706		1,577,006	1,156,807	559,613	8,563,926	250,000	3,596,733
Value	$20,231,708	$612,396	$628,244		$2,134,396	$1,521,553	$681,196	$9,882,598	$307,659	$4,463,666
Natural-rock cement—										
Quantity, barrels	7,964,305	607,820	1,343,185	409,200		3,577,340	37,475	796,876	34,000	1,158,409
Value	$4,036,630	$156,855	$657,984	$150,680		$2,135,036	$33,355	$340,669	$20,000	$542,051
Kilns:										
Total number	1,035	23	99	42	86	283	29	299	13	161
Vertical	584	11	71	42		234	5	146	5	70
Rotary	451	12	28		86	49	24	153	8	91
Power:										
Total horsepower	114,092	6,625	7,980	1,520	11,865	20,466	5,150	35,498	2,610	22,378
Owned—										
Engines—										
Steam—										
Number	495	20	37	9	49	80	24	163	12	101
Horsepower	103,811	6,325	6,230	1,520	10,465	18,815	5,150	35,448	2,610	17,248
Gas or gasoline—										
Number	15									15
Horsepower	2,890									2,890
Water wheels—										
Number	21				12	7		1		1
Horsepower	1,854				1,400	354		50		50
Other power—										
Number	9	3	5							1
Horsepower	2,095	300	1,750							45
Rented—										
Electric, horsepower	3,442					1,297				2,145
Electric motors owned—										
Number	474	38	36		90	92	21	137	15	45
Horsepower	17,420	883	1,426		5,175	2,856	900	4,560	825	1,295
Supplied to other establishments, horsepower	20				20					

APPENDIX.

DIGEST OF UNITED STATES PATENTS RELATING TO CEMENT.[1]

371—October 6, 1837. E. C. WARNER. *Mode of manufacturing hydraulic cement from basanite.*

Basanite Lydian stone, sometimes called "touchstone," is calcined to a red heat and ground.

119413—September 26, 1871. D. C. SAYLOR. *Improvement in the manufacture of cement.*

A hydraulic cement is produced from argillo-magnesian and argillo-calcareous limestone.

126989—May 21, 1872. D. C. SAYLOR. *Improvement in the manufacture of hydraulic cement.*

Argillo-magnesian limestone is burned and crushed, one-fifth of its weight of raw stone is added thereto, and the mass is then ground.

154641—September 1, 1874. F. E. and W. L. BROWN. *Improvement in hydraulic cement.*

Coralline, coral rock, or fossil coral is used for the manufacture of hydraulic cement.

167653—September 14, 1875. C. F. DUNDERDALE. *Improvement in hydraulic cement.*

Kaolin, or other silicate of aluminum, fuller's earth, and lime are mixed, burned, and ground.

174387—March 7, 1876. A. SMITH. *Method of manufacturing lime and cement.*

Lime, or cement rock, is burned with oil, delivered into the combustion chamber in a fluid state, in spray, or as vapor, along with steam, superheated or not, and air.

176938—May 2, 1876. C. F. DUNDERDALE. *Improvement in the manufacture of artificial hydraulic cement.*

The cement materials are crushed and mixed in water in a dense, semifluid state, flowed direct onto a drying floor or pan, then pressed and burned.

195749—October 2, 1877. C. F. DUNDERDALE. *Improvement in compositions for making hydraulic cement.*

It consists of infusorial silica and a silicate of aluminum with lime, burned and ground.

204532—June 18, 1878. W. J. BUDINGTON. *Improvement in the manufacture of hydraulic cement.*

A cement made of fossiliferous limestone and blue clay.

205253—June 25, 1878. J. DIMELOW. *Improvement in the manufacture of hydraulic cement.*

A hydraulic cement formed of rotten, decomposed, or refuse limestone or marble, and the deposit of rivers, in about equal proportions.

205616—July 2, 1878. U. CUMMINGS and L. J. BENNETT. *Improvement in the manufacture of hydraulic cement.*

The method consists in first crushing and disintegrating the calcined and the vitrified portions of the cement stone, then separating the vitrified portion by screening or bolting and reducing the vitrified portion separately to powder.

212094—February 11, 1879. J. A. FRANCIS. *Improvement in the manufacture of hydraulic cement.*

It consists in the use of blue clay combined with coal ashes and sewer mud.

213459—March 18, 1879. C. H. SLICER. *Manufacture of Portland cement.*

The cement making material consists of ground oyster shells, raw or burned, mixed with siliceous clay.

217415—July 8, 1879. J. K. SHINN. *Manufacture of lime and cement.*

To rapidly produce lime and cement, the raw material is subjected, while burning, to the action of a forced blast, continued until burning is complete, and the forced blast is then sustained to effect rapid cooling.

222004—November 25, 1879. C. BROWN. *Improvement in the manufacture of artificial hydraulic or Portland cement.*

The mixed raw material is molded into hollow cylindrical forms or perforated sphere balls.

223815—January 27, 1880. F. RANSOME. *Manufacture of cement and artificial stone.*

A white or artificially tinted cement is made from a mixture of kaolin or china clay and chalk or marble, by burning in muffle-kilns or retorts without contact with fuel.

230865—August 10, 1880. A. T. EASTERBY. *Hydraulic cement.*

Travertine is employed for the manufacture of hydraulic cement.

231172—August 17, 1880. H. JORDAN. *Cement compound.*

A cement compound, to be calcined, composed of silica, oxide of iron, and alumina, combined with the refuse from soda works, composed of lime, soda, potash, magnesia, and alum, tempered with refuse from gas works or tanneries.

231858—August 31, 1880. E. SOLVAY. *Process for the manufacture of cement.*

The residue from the decomposition of calcium chloride by a silicate of aluminum, such as clay, is used as the basis for the manufacture of cement.

237500—February 8, 1881. J. DIMELOW and R. M. PEADRO. *Manufacture of hydraulic cement and lime.*

Rotten or decomposed limestone is burned and then subjected to currents of air or steam in a tightly closed receptacle, and the material then sifted, with or without grinding.

245574—August 9, 1881. J. B. SPEED. *Treatment of hydraulic cement in the kiln.*

Steam is admitted to the mass after it has fallen below the point where it is burned.

245699—August 16, 1881. W. J. BUDINGTON. *Manufacture of hydraulic cement.*

It is made of white marble of the second formation and blue clay.

[1] Printed copies of patents are sold by the Commissioner of Patents at 5 cents each.

249548—November 15, 1881. J. Reese. *Preparing, indurating, and solidifying calcareous lining materials for furnaces.*

Lime is mixed with carbon or a hydrocarbon, then subjected to a high temperature in a cupola until fusion takes place, and, finally, run into suitable shapes for linings.

256103—April 4, 1882. V. Einaigl. *Manufacture of artificial stone.*

A mixture of carbonate of sodium, carbonate of potassium, calcined quartz sand, oxide of calcium, oxide of magnesium, clay, and siliceous sand forms an artificial stone. A hydraulic cement is produced without calcination by adding to 120 parts of said mixture 300 parts of carbonate of lime, 200 parts of oxide of calcium, of which 150 parts are previously slaked, and 380 parts of brick-dust.

260546—July 4, 1882. E. J. De Smedt. *Manufacture of hydraulic lime and hydraulic cement.*

The lime of cement stone is treated, at the time of calcination or afterwards, to a red heat while in contact with carbonic acid.

263310—August 29, 1882. W. F. Browne. *Process of and means for manufacturing a heating fuel for burning lime, etc.*

The products of combustion are exhausted from a lime kiln, and forced by a jet of gaseous vapor under pressure into a carbureting chamber, where the mixture is enriched with oil vapor; it is then forced under pressure into the kiln, whereby the hot products of combustion and gases are circulated through the latter, thus insuring uniform burning.

263873—September 5, 1882. E. J. De Smedt. *Manufacture of hydraulic cement.*

Slow-setting hydraulic cement is produced from cement stone containing an excess of free anhydrous lime, by adding to the calcined stone, before or after grinding, sufficient water to combine with the free anhydrous lime, forming calcium hydrate.

270097—January 2, 1883. J. Murphy. *Hydraulic cement.*

It is composed of iron slag, soapstone, and burned or roasted clay and lime, in the proportions of 2 parts of slag to 1 part of each of the other ingredients.

270608—January 16, 1883. L. Roth. *Manufacture of cement.*

A cement is formed by calcining and grinding a mixture of bauxite, or minerals similar to bauxite, with quartz, hydrated silicic acid, infusorial earth, blast-furnace slag or other silicates, and lime, either as limestone, chalk, or burnt lime, with or without admixture of dolomite, oxide of iron, raw soda, alkali ash, or other fluxes.

274288—March 20, 1883. E. J. De Smedt. *Art of manufacturing Portland cement.*

A hydrocarbon or other combustible is added to and mixed with the cement material prior to calcining.

274734—March 27, 1883. E. J. De Smedt. *Manufacture of Portland cement.*

Enough lime is combined with cement rock or hydraulic limestone, either before or after calcining, to bring the percentage of lime up to about 70 per cent.

274735—March 27, 1883. E. J. De Smedt. *Manufacture of Portland cement.*

Enough dolomite is combined with cement rocks or hydraulic limestone, either before or after calcining, to bring the percentage of lime and magnesia up to about 70 per cent.

275369—April 10, 1883. E. J. De Smedt. *Hydraulic cement compound.*

A cold, slow-setting hydraulic cement, composed of not more than 50 per cent in bulk of a slaty or siliceous non-cement producing rock in combination with not less than 50 per cent of the hot, quick-setting cement rock in common use for cement manufacture.

279354—June 12, 1883. E. J. De Smedt. *Art of manufacturing Portland cement.*

Natural rock is calcined, ground, formed into a cement paste, and then recalcined and reground.

281965—July 24, 1883. W. J. Budington. *Cement compound.*

It is composed of the variegated marble of the second formation (dark and white), and blue clay.

287941—November 6, 1883. W. Jones. *Hydraulic Portland cement.*

Hydraulic Portland cement is made from argillaceous limestone or dolomite containing an excess of clay, by mixing therewith lime or its carbonate in such quantity that the mixture shall contain 70 to 80 per cent of carbonate of lime, then molding, calcining, and grinding.

292329—January 22, 1884. R. W. Lesley and J. M. Willcox. *Manufacture of Portland cement.*

The pulverized cement material is dampened slightly so that it is still a powder and not a paste, molded into balls or lumps by hard pressure, and then calcined and ground.

294080—February 26, 1884. L. Roth. *Manufacture of cement.*

A mixture of blast-furnace cinder, say 100 pounds; carbonate of lime, 135 pounds; and an alkaline chloride, such as carnallite, 15 to 20 pounds in a saturated solution, is calcined and ground.

300790—June 24, 1884. J. Murphy. *Hydraulic cement.*

It is composed of fibrolite, margarite, iron slag, shell marl, and clay, mixed, burned, and ground.

305201—September 16, 1884. R. W. Lesley. *Manufacture of Portland cement.*

Lime, or lime and magnesia in any of their forms, and slate are mixed in substantially such proportions as to make the manufactured cement analyze about 70 per cent of lime, or lime and magnesia, to 30 per cent of alumina and silica, then calcined and ground.

305753—September 30, 1884. R. W. Lesley. *Manufacture of hydraulic cement.*

A slow-setting hydraulic cement is made by mixing ferruginous earths or stones, such as are used in the manufacture of the mineral brown and red paints of commerce, with quick-setting cement rocks in suitable proportions, and then calcining and grinding.

305754—September 30, 1884. R. W. Lesley and D. Griffiths. *Manufacture of Portland cement.*

Iron slag or cinder, as an essential ingredient, is mixed with lime, or lime and magnesia in any of their forms, and calcined and ground, the proportions being such as to bring the percentage of lime, or lime and magnesia, up to about 70 per cent.

305970—September 30, 1884. S. H. Short. *Manufacture of hydraulic cement.*

A mixture of limestone containing from 5 to 15 per cent of clay and from 3 to 10 per cent of magnesia, mixed with a clay containing about 60 per cent of carbonate of lime, 30 per cent of silica, and 10 per cent of magnesia and alkaline carbonates, is formed into bricks, burned, and ground.

309150—December 9, 1884. E. F. Loiseau. *Art of manufacturing Portland cement.*

The cement powder is kept in a granular condition before it goes upon the rolls, by the addition of "binders" of larger size than the cement powder, and composed preferably of coke dust, coal, culm, raw cement, or limestone.

309270—December 16, 1884. S. T. Wellman and G. W. Goetz. *Plant for and process of making lime.*

The process or mode of expelling or driving off carbonic acid gas by driving or drawing through the limestone air which has been more or less highly heated.

311895—February 10, 1885. D. Griffiths. *Manufacture of hydraulic cement.*

Raw rocks containing silica, preferably slates or argillo-calcareous limestones, and slaked lime, are incorporated with calcined cement rock or hydraulic limestone of the kind that produces hot, quick-setting cement.

313217—March 3, 1885. R. W. Lesley. *Manufacture of Portland cement.*

Black or dark-colored cement is produced by incorporating black chalk with the cement material after calcination.

315711—April 14, 1885. R. Bryce. *Manufacture of hydraulic cement.*

Leitchfield marl or shale, say 5 parts, and limestone 11 parts, are ground together, compressed into bricks, calcined, and ground.

321120—June 30, 1885. R. W. Lesley and D. Griffiths. *Art of manufacturing Portland cement.*

To destroy the clinker bridge formed in a kiln during the operation of calcining cement making material to a clinker, a current of cold air is directed against the underface of said bridge to effect the cooling, contraction, and breaking down of the same.

321121—June 30, 1885. R. W. Lesley and D. Griffiths. *Manufacture of cement.*

Cement is artificially seasoned after grinding by submitting it to the action of a forced current of air charged with moisture.

321589—July 7, 1885. J. Dimelow. *Manufacture of hydraulic cement.*

Decomposed limestone is employed for the manufacture of cement.

330602—November 17, 1885. H. Mathey. *Manufacture of cement.*

Cement rock is ground to a fine powder, which is then calcined.

331243—November 24, 1885. W. Joy. *Manufacture of cement.*

Wet slurry or a mixture of wet slurry and fuel is charged into a cement kiln, in successive portions, on the burning charge, at the parts where the charge is burning most freely.

333370—December 29, 1885. J. M. Willcox. *Manufacture of Portland cement.*

Powdered cement making material is mixed with a binding medium, which will be made soft and fluid by heat and which will harden when cooled—such as pitch—and molded and calcined, the binder finally volatilizing in the furnace.

339673—April 13, 1886. H. Mathey. *Manufacture of cement.*

Crushed rock is calcined in a revolving cylinder, and then pulverized.

340357—April 20, 1886. F. Ransome. *Manufacturing cement, etc.*

The cement material, reduced to a powder, is burned in a revolving furnace while exposed to the flame of producer gas mixed with a suitable amount of oxygen.

342784—June 1, 1886. U. Cummings. *Manufacture of cement.*

The cement making material consists of about 1,266 parts of gypsum by weight and of 400 parts of clay.

343182—June 8, 1886. H. Mathey. *Manufacture of hydraulic cement.*

The process consists in pulverizing natural cement rock, adding alluvial clay, mixing, and finally burning under agitation.

343183—June 8, 1886. H. Mathey. *Manufacture of hydraulic cement.*

Cement is colored by adding a metallic oxide to the burned cement rock before final pulverization.

343184—June 8, 1886. H. Mathey. *Manufacture of hydraulic cement.*

A pulverized metallic ore roasted to an oxide is added to the roasted cement of No. 343182 and the mixture ground.

343913—June 15, 1886. H. C. and D. Millen. *Process of manufacturing hydraulic cement.*

Fresh broken clay and marl are piled in alternate layers and allowed to remain until the clay absorbs the surplus moisture of the marl, when the mass is removed in vertical slices, reduced to a plastic condition, cut into blocks, dried, calcined, and ground.

346525—August 3, 1886. J. Anderson. *Making hydraulic cement.*

Crushed cement or limestone rock is immersed in a solution of acetic acid of moderate strength for about three hours, and then calcined, Roman cement being produced if calcined to a red heat and Portland cement if the calcining is carried to a white heat.

347367—August 17, 1886. J. Murphy and N. W. Lord. *Hydraulic cement.*

It consists of limestone, furnace slag, salt, and clay mixed, burned, and ground.

350415—October 5, 1886. U. Cummings. *Hydraulic cement.*

The process of hydrating hydraulic lime or cement consists in exposing the calcined and pulverized material, while in motion or agitation, to an atmosphere of steam.

358437—March 1, 1887. James and John D. Druecker. *Process of burning lime.*

The hot air is drawn from the top of the kiln and forced back to the fire by means of a blast.

373992—November 29, 1887. S. Lowden. *Manufacture of cement.*

First, a mixture of clay, 1 part, and chalk or limestone, 5 parts, is burned at a white heat and crushed; second, limestone is crushed separately and roasted at about 210° F.; and third, the products are mixed in the proportion of 3 parts of the first to 1 part of the second.

375599—December 27, 1887. R. Bosse, E. Friese, and F. Wolters. *Hydraulic and other cements.*

A cement composed of blast-furnace or other slag reduced to granular form, sand, and slaked lime, with or without silicic acid. Also process of making same.

382376—May 8, 1888. J. Murphy. *Hydraulic cement.*

Same as No. 347367, with the omission of the salt.

387199—July 31, 1888. G. L. Eagan. *Hydraulic cement compound.*

A combination of lime rock, silex, mineral magnesite, and alumina.

387588—August 7, 1888. C. R. Costling. *Process of manufacturing hydraulic cement.*

The cement material is crushed and ground, mixed with water to a plastic state and reground in this condition, next dried in a suitable chamber, and then calcined and again ground.

394663—December 18, 1888. J. T. Rigby. *Manufacture of cement from lime-mud.*

Lime-mud, the residue of alkali works, is washed and treated with carbonic acid, until sulphureted hydrogen ceases to be given off and then with sufficient alkaline silicate to decompose the alkaline-earth chlorides, when it is mixed with clay for the manufacture of cement.

397373—February 5, 1889. R. W. Lesley. *Manufacture of cement.*

In the manufacture of cement from slags, the lime or other ingredients, in a finely divided condition and at a high heat, are injected into the slag while still fluid.

399496—March 12, 1889. G. E. Carleton. *Method of calcining rock.*

An air blast is induced underneath the fuel to increase the draft, and a spray of steam or water within the arch above the fuel to regulate the heat.

402511—April 30, 1889. U. Cummings. *Cement.*

A hydraulic cement consisting of silicate of magnesium calcined and pulverized.

417634—December 17, 1889. G. Duryea. *Process of manufacturing cement.*

Fluorspar is mixed with cement-producing materials.

420371—January 28, 1890. J. M. Willcox. *Method of burning cement making materials.*

The cement making material in a kiln or chamber is subjected to the simultaneous action of the usual solid fuel, mixed with the material and forming part of the charge, and of auxiliary burning jets of gas or liquid fuel, applied to the upper strata of the charge before or about the time the lower strata are lighted.

427380—May 6, 1890. E. N. Trump and D. W. Peck. *Method of establishing units of measure in compounding Portland cement.*

Each ingredient is separately molded or cut into forms of uniform size, the sizes varying according to the proportions in which they are to be compounded.

434830—August 19, 1890. W. Joy. *Method of feeding cement kilns.*

Quantities of slurry and fuel mixed and quantities of neat slurry are separately deposited on the burning mass in the kiln at different times as the burning proceeds.

446911—February 24, 1891. H. C. Baum. *Process of manufacturing Portland cement.*

Quicklime is added to wet calcareous marl, and through the resulting chemical action the mixture is rendered perfectly dry preparatory to grinding.

449510—March 31, 1891. G. Williams. *Process of manufacturing cement.*

Carbonate of lime is reduced to powder by steam, under pressure produced from a solution of silicate of soda and water; alumina, silex, and a thin paste of calcium chloride, unslaked lime, and warm water, are then added and the mixture is molded, calcined, and ground.

450750—April 21, 1891. J. B. Speed. *Process of manufacturing hydraulic cement.*

The rock is crushed and sized by screening, and the furnace charged with lumps of a uniform size.

453753—June 9, 1891. E. F. Baude. *Manufacture of Portland cement.*

To obtain pure lime for the manufacture of Portland cement from blue limestone, the limestone is first calcined; the calcined lumps are next moistened by dipping in water and quickly removing them, so that only the pure lime will slake; and the pure, slaked lime is then separated from the impure by sifting.

455376—July 7, 1891. H. H. Wing. *Manufacture of cement.*

A mixture composed of a phosphate, as calcium phosphate, and a silicate, such as clay or serpentine, the phosphate predominating (say 100 parts of phosphate rock to 46.29 parts of clay), is calcined.

460509—September 29, 1891. G. H. Kolteyer and G. W. Bartholomew, Jr. *Process of preparing and tempering slurry for Portland cement.*

Freshly dug clay and lime materials are mixed in proportions determined by weight, worked while soft, damp, or wet, a portion of the mixed mass tested to determine proportions, and the proportions corrected, if necessary, by adding material.

460697—October 16, 1891. J. H. Wright. *Hydraulic lime.*

Lime, slaked in a solution of crude potash, crude soda ash, and alum which has been boiled and cooled, is mixed with an equal quantity of lime slaked by dipping or sprinkling with sulphuric acid or with plaster of Paris, and the mixture is ground to a powder.

464515—December 8, 1891. J. F. Navarro. *Process of manufacturing hydraulic cement.*

The raw ground rock is burned in a vertical kiln and pulverized; the required additional element is then added, the pulverized mixture is calcined in a rotary kiln, and the product is ground.

464516—December 8, 1891. J. F. Navarro. *Process of manufacturing Portland cement.*

Argillaceous rock containing the constituents of Portland cement is ground in a dry state; when deficient in lime, a definite proportion of cement rock high in lime, or of pure limestone ground raw, is added; the powders are mixed dry and calcined in a rotary kiln, and the clinker is ground.

465330—December 15, 1891. C. Tomkins. *Process of manufacturing cement.*

Highly heated slag as it comes from the furnace and before cooling is subjected to a bath of hydrate of lime, and then dried and pulverized.

486165—November 15, 1892. H. J. Livingston. *Composition of matter for producing Portland cement.*

It consists of 11 parts of shell containing 90 per cent and upward of carbonate of lime, 2 parts of alluvial clay, and 1 part of ground chalk flints.

486706—November 22, 1892. C. Van Forell. *Artificial Portland cement.*

Pulverized Roman cement is mixed with pure hydrate of calcium in the form of a dry powder so that the lime and the hydraulic factors are in the proportion of 17 to 10.

486707—November 22, 1892. C. Van Forell. *Artificial Roman cement.*

Pulverized Roman cement containing an excess of lime is mixed with powdered silicate of aluminum so that the lime and the hydraulic factors are in the proportion of 17 to 10.

491280—February 7, 1893. B. Dreyfuss. *Cement.*

A mixture of 2 parts of pulverized spent lime and 1 part of pulverized coke slag, with one-twentieth of its weight of slaked rock lime, and sand.

494763—April 4, 1893. V. F. L. Smith. *Cement.*

A dry-ground mixture of ordinary cement with sand, gravel, or other filling material.

497785—May 23, 1893. M. L. Griffin. *Manufacture of Portland cement.*

Precipitated carbonate of lime, produced by the addition of lime to a soluble carbonate, such as sodium carbonate, is mixed with clay or other aluminous material, dried, calcined, and ground.

506029—October 3, 1893. J. F. Barrow. *Production of lime.*

The products of combustion are exhausted from the bosh of the kiln, so that air may enter the furnace without mixing to an appreciable extent with the said products.

511938—January 2, 1894. S. Dentler. *Manufacture of cement.*

It is composed of slaked lime, carbonate of potash, sulphate of copper, and sulphate of iron.

515017—February 20, 1894. E. L. Ransome. *Slaking lime.*

The clinker produced in burning combustible material containing lime is slaked, disintegrated, and cooled by passing steam through the burned mass before it is withdrawn from the furnace.

515757—March 6, 1894. G. J. Everett. *Cement compound.*

It is composed of a cement which is itself hydraulic, chloride of calcium, and lime.

523645—July 24, 1894. B. K. Rigby. *Manufacture of cement.*

"Ammonia-soda," or "Chance" waste is washed to remove soluble impurities, then tested chemically, and lime added until the impurities, other than soda and sodium chloride, are below 3.5 per cent, when it is mixed with aluminous material, calcined, and ground.

526910—October 2, 1894. B. K. Rigby. *Manufacture of cement.*

A mixture of Le Blanc lime, mud, and clay is calcined until overburning takes place and then ground.

530247—December 4, 1894. G. W. A. Stein. *Method of manufacturing hydraulic cement.*

From 5 to 10 per cent of slag, sand, and hydrate of lime is mixed with the raw cement materials to prevent disintegration before burning in a kiln.

543452—July 23, 1895. H. H. Pierce. *Process of treating lime.*

Quicklime is slaked to a putty, then roasted and ground.

544706—August 20, 1895. J. Whiting. *Manufacture of cement.*

It is composed of pulverized blast-furnace or other slag, caustic soda, and slaked lime, all in the dry state.

545552—September 3, 1895. W. R. Taylor. *Apparatus for burning cement making materials and process of obtaining carbon dioxide.*

The materials are heated in direct contact with gaseous products of combustion until the moisture, organic matter, and the like are drawn off and the temperature reached at which carbonic acid is given off, when the heating is continued out of contact with the gaseous products of combustion.

550619—December 3, 1895. E. H. Hurry and H. J. Seaman. *Process of and apparatus for manufacture of cement.*

The cement material is roasted, the hot clinker partially cooled, broken, and wetted, and the moisture evaporated from the broken material in a continuous process.

562982—June 30, 1896. G. W. A. Stein. *Hydraulic cement.*

A small quantity of ground slag sand or granulated furnace slag is added to a finished mixture of raw cement to make the sintered mixture brittle, so that on cooling the mass crumbles.

568599—September 29, 1896. C. Bonneville. *Method of and apparatus for calcining cement.*

Raw cement material and cement proper are combined with a combustible material, in an intimately mixed and plastic mass, and are then subjected to a simultaneous rolling and calcining operation by which the mass is formed into separate lumps immediately before, and the combustible material burned out upon and immediately after the setting of the cement proper.

569833—October 20, 1896. S. Jorgensen. *Slag cement.*

To ordinary slag cement, which is composed of ground slag and slaked lime, is added a roasted and powdered mixture of ground slag, slaked lime, and water.

582068—May 4, 1897. R. W. Lesley. *Hydraulic cement.*

To produce a slow-setting Portland cement the cement making material, after calcination, and in the form of either clinker or powder, is treated with dilute sulphuric acid.

584397—June 15, 1897. M. W. L. Nahnsen. *Manufacture of cement.*

The residues from the manufacture of sulphate of aluminum are freed from components soluble in water and the remainder mixed with lime, without being burned.

590057—September 14, 1897. W. H. Fahrney. *Method of calcining friable materials.*

The material to be calcined is formed into a tube and continuously projected into the furnace, the heat of which passes up through the tube.

592492—October 26, 1897. V. Kjeldsen. *Cement manufacture.*

From 3 to 5 per cent of manufactured cement is added to the raw material and the mixture formed into blocks, which are burned and ground.

599792—March 1, 1898. H. H. Pierce. *Process of treating lime.*

Quicklime is slaked to a putty, roasted in the presence of carbonic acid gas, and ground.

606278—June 28, 1898. C. J. Curtin. *Process of making slag cement.*

Burnt lime, to which has been added 3 per cent of hydrochloric acid, is immersed in about 20 per cent of water, thoroughly mixed and combined with 85 per cent of molten slag, and then dried and pulverized.

617241—January 3, 1899. A. D. Elbers. *Process of treating blast-furnace slag for cement.*

Pulverized blast-furnace slag is superficially desulphurized by the application of a weak solution of nitric acid, and then alkalized by impregnation with an aqueous solution of sodium carbonate.

620155—February 28, 1899. H. J. Livingston. *Composition for making carbonated, hydraulic lime, cement, or mortar.*

It consists of 100 parts of hydrate of lime, 30 to 40 parts of coke, and 1 part of saccharine or farinaceous matter by weight.

622387—April 4, 1899. H. H. Pierce. *Cement.*

Quicklime is slaked to a putty; pulverized sulphate of lime is then added, the mixture is roasted, and the roasted product is then reduced to a powder.

622388—April 4, 1899. H. H. Pierce. *Treatment of lime.*

Quicklime is slaked to a putty; pulverized carbonate of lime is then added, the mixture is roasted, and the roasted product is reduced to a powder.

636865—November 14, 1899. C. Straub. *Process of treating calcium oxide.*

Calcined lime is partially hydrated, and then recalcined until all moisture is expelled.

643856—February 20, 1900. W. S. O. Muth. *Manufacture of cement.*

Burnt lime is hydrated with water containing a soluble salt which will evolve oxygen at a high temperature, such as nitrate of soda, and the hydrated lime is mixed with powdered blast-furnace slag, and then calcined.

651684—June 12, 1900. G. M. Westman. *Process of manufacturing lime and carbonic acid.*

The process consists in heating a mixture of carbonic acid and steam, passing this mixture through limestone, drawing off the expelled carbonic acid and lime produced, bringing the expelled carbonic acid in contact with water to convert the latter into steam and form a mixture of steam and carbonic acid, reheating a part of the mixture thus formed, and forcing the mixture back into and through the limestone.

655501—August 7, 1900. L. H. M. Merceron-Vicat. *Artificial cement.*

Marly limestone is calcined, and then fused under oxidizing conditions, thereby removing the sulphur while in a state of fusion.

667255—February 5, 1901. A. S. Schubert and F. J. Pierce. *Process of producing lime and cement and fixed combustible gases.*

The gases distilled off from a mass of raw cement and fuel are passed through a mass of incandescent carbonaceous material, from which air is excluded; the residuum is subsequently clinkered, the heat evolved in the clinkering process being utilized for distilling and partially burning a subsequent charge.

670047—March 19, 1901. G. M. Westman. *Process of manufacturing lime and carbonic acid.*

This is a continuous process of treating limestone with a highly heated mixture of carbonic acid and steam, consisting in expelling the carbonic acid from the limestone, bringing the hot carbonic acid in contact with water to convert the latter into steam, mixing the steam with the expelled carbonic acid, and then reheating the mixture and again passing it through the limestone, thus producing lime and carbonic acid of maximum purity.

678412—July 16, 1901. W. Lessing. *Process of burning cement, gypsum, etc.*

The raw material is ground, heated to a white heat, and dropped downward against a column of flame; it is then utilized, in its intensely heated condition, to generate steam for the preliminary warming of fresh material.

678748—July 16, 1901. G. Miller. *Process of forming pieces of raw cement.*

Pieces of dried cement are passed successively through a series of drying drums, each containing a plastic mass of raw cement.

682837—September 17, 1901. C. M. Avery. *Process of pulverizing calcium oxide or lime.*

The lime, as it comes from the kiln, is subjected to simultaneous agitation and sifting in the presence of steam.

683188—September 24, 1901. F. N. Spear. *Process of treating lime.*

Finely divided quicklime is subjected to the action of steam in a closed chamber, and then brought into contact with carbonic acid gas obtained from a calcining kiln.

685064—October 22, 1901. A. S. Schubert. *Process of producing lime or cement and combustible gases.*

Heated products of the combustion of burning fuel are passed through raw cement material, thereby expelling gaseous matter therefrom, the resultant gases being subsequently passed through a body of highly heated fuel.

688910—December 17, 1901. G. Warren. *Manufacture of cement or similar materials.*

The liquid sludge is run into molds and dried, to form blocks for calcination.

691397—January 21, 1902. J. D. McDonnell. *Cement.*

It consists of water, carbolic acid, nitro-muriatic acid, nitric acid, crushed calcareous rock, sulphate of calcium, and cement of any manufacture.

692257—February 4, 1902. C. E. Eldred. *Method of calcining lime, etc.*

In place of the ordinary pure-air draft, an artificially accelerated draft composed of air and a neutral gaseous diluent—kiln gases—is

used to promote combustion, thereby greatly retarding the liberation of the heat units of the fuel and producing a long flame of large volume.

698268—April 22, 1902. O. Friz. *Process of making cement.*

To produce a white cement, a mixture of lime, clay as free as possible from iron, and feldspar is burned to the verge of fusion—that is, beyond the sintering limit.

702009—June 10, 1902. F. G. Jordan. *Process of making cement.*

Limestone is decarbonated and siliceous clay mixed therewith while in an incandescent state; the mixture is then ignited in the presence of a hydrating agent, molded, calcined, and ground.

704849—July 15, 1902. J. T. McKim. *Cement.*

A compound to be added to Portland or similar cement, consisting of calcareous ocher, iron ore plant, and litharge, ground and subjected to a heat of 160° F.

705542—July 22, 1902. M. T. J. Ochs. *Plaster composition.*

It consists of a mixture of 2 parts of hydraulic cement, 1 part of powdered silicate of aluminum, and 1 part of powdered carbonate of lime.

705650—July 29, 1902. V. Conti, G. De Geofrey, and G. Le Gall du Terte. *Artificial stone.*

A mixture of 15 parts of aluminum sulphate, 15 parts of pulverized Kieselguhr, 50 parts of calcined magnesia, 25 parts of magnesium chloride, and 75 parts of magnesium sulphate, all by weight, together with inert matter.

706760—August 12, 1902. W. R. Knox. *Hydraulic fireproof cement.*

A ground but unburned mixture composed of about 24 parts of silica, 6½ parts of alumina, 5 parts of magnesia, 60 parts of lime, 3 parts of hydrochloric acid, and 1½ parts of iron oxide.

707788—August 26, 1902. J. Murphy. *Composition of matter.*

It consists of crushed, hard iron slag, pulverized hard-lined cinders, Portland cement, liquor of flints, and water.

714842—December 2, 1902. R. F. Wentz. *Art of manufacturing cement.*

Cement ore is calcined by the combustion of pulverized carbon, utilizing also the heat from the gaseous products, derived from the disintegration of highly heated cement clinker when treated with water and air.

CLAY

CLAY.

By Jefferson Middleton.

This report covers the operations of the clay mining industry in the United States during the year 1902. By far the larger portion of the clay mined is used by the miner in the manufacture of clay products, but as the work of winning the clay is such an intimate part of the process of manufacture as to make its segregation impossible, only the clay mined and sold as such has been included in the report. The statistics for the clay working industries were shown in the Twelfth Census Report on Manufactures.

The clay mining industry seems to have received but little attention at previous censuses. Statistics were first shown at the census of 1860, when 5 mines were reported, all in Middlesex county, N. J., with a product valued at $105,660. At the census of 1870, 1 fire clay establishment was reported from Jackson county, Mich., with a product valued at $80,000. At the census of 1880 statistics were presented for 9 kaolin mines—4 in Delaware, 2 in South Carolina, and 1 each in Indiana, Maryland, and New York—reporting 23,277 tons of clay, valued at $200,457. The Eleventh Census contains no statistics for clay mining as a distinct industry.

Clay mining was carried on in 27 states, but in most of them the industry was of minor importance. In only 6 of the states did the product exceed a value of $100,000, and the product for these states was 68.7 per cent of the total value of products for the United States.

The following table is a summary of the statistics for 1902:

Table 1.—*Summary: 1902.*

Number of mines	205
Number of operators	203
Salaried officials, clerks, etc.:	
Number	185
Salaries	$150,505
Wage-earners:	
Average number	2,433
Wages	$958,892
Contract work	$13,241
Miscellaneous expenses	$126,873
Cost of supplies and materials	$272,823
Product:	
Quantity, short tons	1,455,357
Value	$2,061,072

While there were 205 mines reported, they were owned by 203 operators, showing that the clay mining industry is as yet largely local, the modern tendency to combination not having affected it. Of the mines, 34 were in New Jersey, 31 in Ohio, and 25 in Missouri. The number in the other states varied from 19 in Pennsylvania to 1 in several of the states.

In addition to the active mines, 61 idle mines were reported, distributed as follows: 12 in Ohio, 6 in Tennessee, 5 in Maryland, 4 each in Georgia and Pennsylvania, 3 each in Colorado, Missouri, North Carolina, and Virginia, 2 each in California, Illinois, Indiana, Kentucky, Massachusetts, and Vermont, and 1 each in Michigan, New Hampshire, New Jersey, New York, South Carolina, and West Virginia. There were also 2 mines—1 each in North Carolina and Florida—at which development work only was reported.

Capital stock of incorporated companies.—Table 2 presents the details of the capitalization of the 45 incorporated companies reporting capitalization. It shows that of the 203 operators of clay mines 52 were incorporated companies, of whom 45 reported an authorized capital stock of $6,947,600. The total number of shares authorized was 660,536, and the total number of shares issued was 341,107, with a par value of $5,275,200. The dividends paid during the year amounted to $59,190. The authorized stock was divided into 650,986 shares of common stock, with a par value of $6,272,600, and 9,550 shares of preferred stock, with a par value of $675,000. Of the common stock, however, only 332,377 shares (par value, $4,637,200) were issued, while 8,730 shares of preferred stock (par value, $638,000) were issued. The bonds issued were 717 in number, with a par value of $331,000, on which the sum of $18,110 was paid as interest. The only states in which companies reported preferred stock were Georgia, Delaware, and New Jersey, while bonds were authorized and issued only in the two last named states and in Pennsylvania. In West Virginia bonds to the value of $15,000 were authorized, but none were issued. In only 1 state (Wisconsin) were assessments levied.

TABLE 2.—CAPITALIZATION OF INCORPORATED COMPANIES: 1902.

	United States.	California.	Colorado.	Delaware.	Georgia.	Illinois.	Kentucky.	Missouri.
Number of incorporated companies	52	2	1	5	4	1	4	2
Number reporting capitalization	45	1	1	5	4	1	4	2
Capital stock and bonds issued	$5,606,200	$200,000	$30,000	$1,146,000	$235,900	$5,000	$25,400	$492,200
Capital stock:								
Total authorized—								
Number of shares	660,536	500,000	30,000	18,200	6,500	100	2,206	5,210
Par value	$6,947,600	$500,000	$30,000	$1,370,000	$650,000	$5,000	$210,600	$521,000
Total issued—								
Number of shares	341,107	200,000	30,000	11,850	2,359	100	354	4,922
Par value	$5,275,200	$200,000	$30,000	$1,140,000	$235,900	$5,000	$25,400	$492,200
Dividends paid	$59,190			$10,000			$7,380	
Common—								
Authorized—								
Number of shares	650,986	500,000	30,000	14,200	6,000	100	2,206	5,210
Par value	$6,272,600	$500,000	$30,000	$970,000	$600,000	$5,000	$210,600	$521,000
Issued—								
Number of shares	332,377	200,000	30,000	7,850	2,079	100	354	4,922
Par value	$4,637,200	$200,000	$30,000	$740,000	$207,900	$5,000	$25,400	$492,200
Dividends paid	$55,690			$10,000			$7,380	
Preferred—								
Authorized—								
Number of shares	9,550			4,000	500			
Par value	$675,000			$400,000	$50,000			
Issued—								
Number of shares	8,730			4,000	280			
Par value	$638,000			$400,000	$28,000			
Dividends paid	$3,500							
Bonds:								
Authorized—								
Number	90,747			2				
Par value	$436,000			$6,000				
Issued—								
Number	717			2				
Par value	$331,000			$6,000				
Interest paid	$18,110			$360				
Assessments levied	$100,000							

	New Jersey.	Ohio.	Pennsylvania.	South Carolina.	West Virginia.	Wisconsin.	All other states.[1]
Number of incorporated companies	9	5	3	5	2	2	7
Number reporting capitalization	9	3	2	4	2	2	5
Capital stock and bonds issued	$1,800,700	$34,000	$1,200,000	$228,000	$75,000	$110,000	$524,000
Capital stock:							
Total authorized—							
Number of shares	25,920	450	11,000	11,500	2,500	200	46,750
Par value	$1,241,000	$45,000	$1,050,000	$250,000	$250,000	$200,000	$625,000
Total issued—							
Number of shares	24,192	340	11,000	11,280	750	110	43,850
Par value	$1,125,700	$34,000	$1,050,000	$228,000	$75,000	$110,000	$524,000
Dividends paid	$15,310		$5,000	$1,500			$20,000
Common—							
Authorized—							
Number of shares	20,870	450	11,000	11,500	2,500	200	46,750
Par value	$1,016,000	$45,000	$1,050,000	$250,000	$250,000	$200,000	$625,000
Issued—							
Number of shares	19,742	340	11,000	11,280	750	110	43,850
Par value	$915,700	$34,000	$1,050,000	$228,000	$75,000	$110,000	$524,000
Dividends paid	$11,810		$5,000	$1,500			$20,000
Preferred—							
Authorized—							
Number of shares	5,050						
Par value	$225,000						
Issued—							
Number of shares	4,450						
Par value	$210,000						
Dividends paid	$3,500						
Bonds:							
Authorized—							
Number	415		90,300		30		
Par value	$175,000		$240,000		$15,000		
Issued—							
Number	415		300				
Par value	$175,000		$150,000				
Interest paid	$8,750		$9,000				
Assessments levied						$100,000	

[1] Includes companies distributed as follows: Connecticut, 1; Florida, 2; Massachusetts, 1; North Carolina, 3.

Delaware, New Jersey, and Pennsylvania are the only states showing a capitalization exceeding $1,000,000.

Employees and wages.—The average number of wage-earners employed during each month in 1902 is shown by states in Table 7. The most active clay mining season was from April to October. This is to be expected when the principal method of mining clay is considered. Probably 90 per cent of the work was done in open pits; this tends to reduce operations in the cold months and in inclement weather. The variation in the number of wage-earners between the months of summer and winter is not as great as might be expected, considering the fact that the work done is almost entirely above ground. The average number of wage-earners, men and boys, for the whole year was 2,433. The largest number of men employed in any one month was 2,624 in June, while the smallest was 2,100 in February. The average number of men employed for the whole year was 2,403. The average number of boys employed during the year was 30, the highest number

being 34 in June and July, and the lowest number 27 in October and November. The largest number of men was employed in New Jersey—697 for the entire year, 798 in July, and 590 in February. The average number of men reported for Pennsylvania was 311 for the whole year, with the largest number in June (338), and the smallest in February (274). South Carolina shows an average of 190 for the year, while the average by months ranged from 167 in August to 216 in May. In Delaware the average for the year was 169, while the greatest number, 197, was reported in June and the least, 103, in February.

Table 3 presents the average number of each class of wage-earners employed at specified daily rates of pay in 1902.

TABLE 3.—*Distribution of wage-earners according to daily rates of pay, by occupations: 1902.*

RATE PER DAY (DOLLARS).	All occupations.	Engineers.	Firemen.	Machinists, blacksmiths, carpenters, and other mechanics.	Miners.	Miners' helpers.	Timbermen and track layers.	Boys under 16 years.	All other wage-earners.
Total	2,433	53	19	34	1,649	17	2	30	629
Less than 0.50	11	.....	.....	.....	.....	.....	.....	9	2
0.50 to 0.74	44	.....	.....	.....	1	.....	.....	13	30
0.75 to 0.99	330	.....	1	.....	275	.....	2	5	47
1.00 to 1.24	495	6	2	7	206	.....	.....	3	270
1.25 to 1.49	871	2	3	5	730	2	.....	.....	129
1.50 to 1.74	321	24	10	12	232	8	.....	.....	36
1.75 to 1.99	89	2	2	.....	34	3	.....	.....	48
2.00 to 2.24	121	11	1	8	76	4	.....	.....	21
2.25 to 2.49	65	2	.....	1	53	.....	.....	.....	9
2.50 to 2.74	68	4	.....	1	29	.....	.....	.....	34
2.75 to 2.99	7	.....	.....	.....	7	.....	.....	.....	.....
3.00 to 3.24	10	1	.....	.....	6	.....	.....	.....	3
3.25 to 3.49	1	1	.....	.....	.....	.....	.....	.....	.....

Of the 2,433 wage-earners of all occupations, 871, or 35.8 per cent, received between $1.25 and $1.49 per day; 495, or 20.3 per cent, between $1 and $1.24; 330, or 13.6 per cent, between 75 and 99 cents; and 321, or 13.2 per cent, between $1.50 and $1.74.

Of the total number, 1,648, or 67.7 per cent, were miners, of whom 730, or 44.3 per cent, received between $1.25 and $1.49 per day, and 231, or 14 per cent, between $1.50 and $1.74; while 276, or 16.7 per cent, received less than $1.

The wage-earners next in number to miners were reported as "all other wage-earners." Of these there were 629, consisting largely of unskilled workmen or common laborers, as is indicated by the low rates shown in the table—399, or 63.4 per cent, having been paid from $1 to $1.49 per day. The other classes of occupations were numerically small.

The rates of pay of engineers, firemen, and mechanics averaged somewhat higher than the rates for miners, while the rates paid to boys ranged from less than 50 cents up to from $1 to $1.24.

Mechanical power.—The total horsepower reported for the industry was 4,478, of which 3,942, or 88 per cent, was steam, the remainder being divided between gas and gasoline engines, water wheels, and "other power." Power is used to a less extent, proportionally to production, in the mining of clay than in many of the other mining industries, clay being taken usually from open cuts, with pick and spade, and without the use of machines.

Production.—Table 4 shows the production of clay from 1897 to 1902, inclusive, by varieties.

TABLE 4.—QUANTITY AND VALUE OF EACH KIND OF CLAY PRODUCED: 1897 TO 1902.

[United States Geological Survey, "Mineral Resources of the United States."]

KIND.	1902		1901		1900		1899		1898		1897	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
All kinds	1,455,357	$2,061,072	1,367,170	$2,576,982	1,221,660	$1,840,377	843,279	$1,645,328	585,450	$1,384,766	563,115	$978,448
Raw	1,203,369	1,319,174	1,019,163	1,273,684	1,028,643	1,207,160	843,279	1,645,328	585,450	1,384,766	563,115	978,448
Prepared	251,988	741,898	348,007	1,303,248	193,017	633,217	.....	.....	.....	.....	.....	.....
Kaolin	123,813	646,777	97,253	584,523	60,114	397,286	97,107	471,282	100,534	496,979	68,743	367,080
Raw	58,343	189,603	37,456	141,399	22,554	108,220	97,107	471,282	100,534	496,979	68,743	367,080
Prepared	65,470	457,174	59,797	442,624	37,560	289,066	.....	.....	.....	.....	.....	.....
Ball	50,527	171,086	[1] 21,008	[1] 68,907	21,381	91,983	22,762	109,369	101,111	154,743	112,926	213,566
Raw	30,000	68,524	21,008	68,907	13,976	53,850	22,762	109,369	101,111	154,743	112,926	213,566
Prepared	20,527	102,562	(1)	(1)	7,405	38,133	.....	.....	.....	.....	.....	.....
Fire	926,896	891,185	929,749	1,514,508	845,559	947,993	478,996	826,919	352,612	672,362	381,446	397,802
Raw	774,532	736,055	680,793	746,956	714,403	685,927	478,996	826,919	352,612	672,362	381,446	397,802
Prepared	152,364	155,130	248,956	767,552	131,156	262,066	.....	.....	.....	.....	.....	.....
Stoneware	91,579	113,842	92,229	114,613	93,529	94,705	.....	.....	.....	.....	.....	.....
Raw	87,147	105,182	87,829	101,753	88,815	83,843	.....	.....	.....	.....	.....	.....
Prepared	4,432	8,660	4,400	12,860	4,714	10,862	.....	.....	.....	.....	.....	.....
Terra cotta (raw)	50,453	54,213	.....	.....	45,077	50,769	91,661	101,744	.....	.....	.....	.....
Pipe	94,874	74,856	.....	.....	42,532	36,134	89,953	57,702	.....	.....	.....	.....
Raw	94,874	74,856	.....	.....	42,407	35,604	89,953	57,702	.....	.....	.....	.....
Prepared	.....	.....	.....	.....	125	530	.....	.....	.....	.....	.....	.....
Miscellaneous	117,215	109,113	226,931	294,381	113,468	221,507	62,800	78,312	31,193	60,682	.....	.....
Raw	[2] 108,020	[2] 90,741	192,077	214,169	101,411	188,947	62,800	78,312	31,193	60,682	.....	.....
Prepared	9,195	18,372	34,854	80,212	12,057	32,560	.....	.....	.....	.....	.....	.....

[1] Prepared ball clay included in "miscellaneous."
[2] Includes 39,157 tons of sand, valued at $35,956, produced in connection with the mining of clay.

It is possible that the figures for some of the years are not strictly comparable, because they may include clay sold, in the raw or the prepared state, by those whose principal business was the manufacture and sale of clay products and not the production of clay. This table shows that the production of clay increased from 563,115 tons in 1897 to 1,455,357 tons in 1902, a gain of 892,242 tons, or 158.4 per cent, while the value increased from $978,448 in 1897 to $2,061,072 in 1902, a gain of $1,082,624, or 110.6 per cent. It is probable that the figures for the first two or three years reported by the Survey are somewhat below the actual output, because they were collected by correspondence—a method by which it takes usually two or three years to secure satisfactory results.

While the quantity of the product for 1902 was the largest recorded, being greater by 88,187 tons, or 6.5 per cent, than in 1901, the value of the product decreased from $2,576,932 in 1901 to $2,061,072 in 1902, a loss of $515,860, or 20 per cent. This decrease in value was due largely to a marked decline in the value of prepared fire clay, which showed a decrease of 38.8 per cent in quantity and of 79.8 per cent in value.

Of the 1,455,357 tons of clay mined in 1902, 1,203,369 tons, or 82.7 per cent, were sold without any preparation whatever after mining, while 251,988 tons, or 17.3 per cent, were prepared at the mine by washing, by grinding, or in some other manner. In 1901, 74.5 per cent was sold raw and 25.5 per cent was prepared at the mine. The average value of all clay at the mine in 1902 was $1.42 per ton; the value of the raw clay was $1.10, and of the prepared, $2.94 per ton. In 1901 these average values were $1.89, $1.25, and $3.74, respectively.

Rank of states.—Table 5 shows the distribution of the value of the clay produced during 1902, by states, ranked according to the value of their product.

New Jersey was by far the most important clay mining state, its product being valued at $612,721, or 29.7 per cent of the total. Pennsylvania ranked second with a product valued at $288,811, or 14 per cent; Delaware was third, with a value of $171,714, or 8.3 per cent; and Missouri, South Carolina, and Ohio were fifth, sixth, and seventh, in the order named, with products valued at $134,862, $107,325, and $101,305, respectively, or 6.5 per cent, 5.2 per cent, and 4.9 per cent. The product of these six states was valued at $1,416,738, or 68.6 per cent of the total. In "all other states" are included, however, two rather important clay producing states, namely, Florida and North Carolina. In these states the clay produced was valued at $221,833, or 87 per cent of the total for "all other states," and 10.8 per cent of the total for the United States. The remaining states were of but relatively small importance, none producing clay valued at as much as $100,000.

TABLE 5.—*Rank of states according to value of clay produced: 1902.*

STATE.	Rank.	Value of product.	Per cent of total.
United States	.....	$2,061,072	100.0
New Jersey	1	612,721	29.7
Pennsylvania	2	288,811	14.0
Delaware	3	171,714	8.3
Florida	4	(1)	.....
Missouri	5	134,862	6.5
South Carolina	6	107,325	5.2
Ohio	7	101,305	4.9
North Carolina	8	(1)	.....
Georgia	9	76,480	3.7
Colorado	10	67,434	3.3
Kentucky	11	44,256	2.2
West Virginia	12	43,266	2.1
Illinois	13	38,463	1.9
Tennessee	14	27,171	1.3
California	15	24,446	1.2
Wisconsin	16	23,178	1.1
Alabama	17	19,742	1.0
Connecticut	18	(1)	.....
New York	19	14,535	0.7
Maryland	20	10,055	0.5
Indiana	21	(1)	.....
Vermont	22	(1)	.....
Utah	23	(1)	.....
Michigan	24	(1)	.....
Massachusetts	25	(1)	.....
Texas	26	455	(2)
Washington	27	(1)	.....
All other states	.....	254,854	12.4

[1] Included in "all other states" to avoid disclosing individual returns.
[2] Less than one-tenth of 1 per cent.

Imports.—The following table is a statement of the clay imported into the United States from 1885 to 1902:

TABLE 6.—IMPORTS OF CLAY, CLASSIFIED BY KINDS: 1885 TO 1902.

[United States Geological Survey, "Mineral Resources of the United States," 1902.]

CALENDAR YEAR.	TOTAL.		KAOLIN, OR CHINA CLAY.		ALL OTHER CLAY.					
					Unwrought.		Wrought.		Common blue.	
	Quantity (long tons).	Value.	Quantity (long tons).	Value.	Quantity (long tons).	Value.	Quantity (long tons).	Value.	Quantity (long tons).	Value.
1885	23,916	$190,460	10,626	$83,722	9,736	$76,899	3,554	$29,839	.....	.....
1886	31,984	257,698	16,590	123,093	13,740	113,875	1,654	20,730	.....	.....
1887	43,318	303,052	23,486	141,360	17,645	139,405	2,187	22,287	.....	.....
1888	45,586	307,989	18,150	102,050	20,604	152,694	6,832	53,245	.....	.....
1889	47,222	324,492	19,843	113,538	19,237	145,983	8,142	64,971	.....	.....
1890	53,950	454,770	29,923	270,141	21,049	155,486	2,978	29,143	.....	.....
1891	62,292	469,629	39,901	294,458	16,094	118,689	6,297	56,482	.....	.....
1892	79,323	655,011	49,468	375,175	20,132	155,047	4,551	64,818	5,172	$59,971
1893	75,056	606,658	49,713	374,460	14,949	113,029	6,090	67,280	4,304	51,889
1894	83,157	653,949	62,715	465,501	13,146	98,776	4,768	60,786	2,528	28,886
1895	102,895	758,484	75,447	531,714	18,419	125,417	5,160	60,775	3,869	40,578
1896	99,534	735,506	76,718	536,081	13,319	88,029	4,514	56,701	4,983	54,695
1897	93,744	652,881	71,938	493,431	9,405	56,264	7,839	52,232	4,562	50,954
1898	108,440	755,268	85,586	573,595	16,130	98,434	1,412	24,959	5,312	58,280
1899	123,074	872,962	92,521	615,717	19,614	118,679	1,716	31,948	9,223	106,618
1900	144,107	962,367	111,959	698,720	21,626	126,203	3,195	45,431	7,327	92,013
1901	157,196	969,777	117,756	663,379	27,597	156,838	5,707	75,721	6,136	73,889
1902	168,551	1,154,805	133,062	883,092	25,831	138,032	2,680	47,093	6,978	86,588

A detailed summary of the clay mining industry for 1902 is given in Table 7.

DESCRIPTIVE.

Popularly, clay is any earthy substance which, if mixed with water and molded, will retain its shape after drying, and which upon subjection to high temperature loses its plasticity and becomes hard and brittle.

Technically, pure clay or kaolinite, which is the basis of all clay, is a hydrated silicate of aluminum, expressed by the formula $Al_2O_3 2SiO_2$, $2H_2O$. All clay in its natural state contains more or less impurities, the kind and quantity of which determine its character; from purest varieties, called kaolin, clays range through all stages of impurity down to a point where the material contains so little kaolinite that it can not be classified as clay at all.

Clay is ordinarily classified as kaolin, ball clay, fire clay, vitrified ware clay, and brick clay; there are also slip clay, and paper clay. Fire clay includes clays used for stoneware and for terra cotta, which are reported separately by the Geological Survey. Vitrified ware clay includes the pipe clay reported by the Survey.

In the following description of the physical and chemical properties of the several kinds of clay, the chemical analysis has been supplemented, wherever possible, by what is called the rational analysis. The ordinary quantitative chemical analysis treats clay as a mixture of oxides, although the elements may be present in entirely different combinations, such as silicates, carbonates or hydrates, sulphates, etc. The nature of these combinations is of importance. For example, silica in the form of quartz, which is infusible, will decrease the shrinkage and up to certain temperatures increase the refractoriness; but if present as a component of feldspar, it serves the purpose of a flux and somewhat increases the plasticity. The advantage of the rational analysis is that it resolves the clay into its mineral components, affording an insight into the physical properties—as fusibility, refractoriness—of the material. This is frequently a matter of far greater importance than the chemical composition; for instance, two clays of the same rational composition will behave much alike if burned under the same conditions, even though they may differ in chemical composition.

Kaolin.—Kaolin is a white burning, nonplastic, highly refractory residual clay used in the manufacture of china and other white wares; it must be practically free from iron, as a very small quantity would cause the ware to become discolored in burning. The chief producing states are Pennsylvania, Delaware, North Carolina, and South Carolina. The following is an analysis of a washed sample of the kaolin from North Carolina, which is one of the best known and most widely used.

Analysis of washed kaolin from North Carolina.[1]

	Per cent.
Silica	45.70
Alumina	40.61
Ferric oxide	1.39
Lime	0.45
Magnesia	0.09
Alkalies	*2.82
Moisture	0.35
Water (loss on ignition)	8.93
	100.39
Free sand	3.19
Total fluxes	4.75
Specific gravity	2.43

The rational analysis is as follows:

Clay substance	96.81
Quartz	0.07
Feldspar	3.12
	100.00

[1] North Carolina Geological Survey, Bulletin No. 13, page 61.

Ball clay.—Ball clay is a white burning, plastic, sedimentary clay, used with kaolin to afford plasticity to the body in the manufacture of white ware, and often incorrectly called kaolin. The distinguishing characteristic of this clay is its plasticity. The chief producers of ball clay for sale are Florida, New Jersey, and Kentucky.

The following is an analysis of ball clay from Florida:

Analysis of ball clay from Florida.[1]

	Per cent.
Silica	46.11
Alumina	39.55
Ferric oxide	0.35
Magnesia	0.13
Sulphuric oxide	0.07
Titanic oxide	1.20
Water	13.78
	101.19

[1] United States Geological Survey, Professional Paper, No. 11, page 39.

Fire clay.—The term fire clay is a rather broad one, embracing not only the high-grade clays used for the manufacture of refractory material of all kinds, but also the more or less impure varieties used for stoneware, terra cotta, and yellow and Rockingham ware. Glass-house supplies, which must be highly refractory, are made from an especially high grade of this clay. Fire clay is subdivided into flint, or nonplastic, and plastic clay. The mining of fire clay for sale is most extensively carried on in New Jersey, Missouri, Pennsylvania, and Ohio.

Analyses of various fire clays.

[Chemical.]

CONSTITUENTS.	FIRE CLAY FROM NEW BRIGHTON, PA.	GLASS-POT CLAY FROM LAYTON STATION, PA.	STONE-WARE CLAY.[1]	ROCKING-HAM AND YELLOW WARE CLAY.[1]
	Per cent.	Per cent.	Per cent.	Per cent.
Silica	61.75	64.89	71.58	60.50
Alumina	23.66	24.08	18.81	25.53
Ferrous oxide	1.93	0.21	.....	.....
Ferric oxide	.....	0.29	1.09	1.66
Lime	0.46	0.41	0.40	0.38
Magnesia	0.35	0.19	0.62	1.19
Alkalies	2.42	1.03	[2] 2.96	1.76
Titanic oxide	1.78	.....	.....	0.54
Manganous oxide	.....	.....	Trace.	0.33
Water	7.20	9.29	5.95	7.98
Total	99.55	100.39	100.91	99.87

[Rational.]

Clay substance	.....	.....	53.42	76.05
Quartz	.....	.....	44.41	19.54
Feldspathic detritus	.....	.....	3.08	4.28
Total	.....	.....	100.91	99.87

[1] Chemistry of Pottery, by Karl Langenbeck.
[2] Combining weight 47 per cent.

Vitrified ware clay.—Clays for vitrified wares, such as sewer pipe, electric conduits, and vitrified paving brick, are those in which the proportion of fluxing impurities is sufficient to allow the clay to vitrify at a moderately low temperature, but not to cause the ware to become soft under the pressure of a column of some height and considerable weight. The following table shows the range of the constituents of clays used for making vitrified paving brick, together with an average analysis of such clays:

Analysis of vitrified paving brick clay.[1]

	Minimum (per cent).	Maximum (per cent).	Average (per cent).
Silica	49.00	75.00	56.00
Alumina	11.00	25.00	22.50
Ferric oxide	2.00	9.00	6.70
Lime	0.20	3.50	1.20
Magnesia	0.10	3.00	1.40
Alkalies	1.00	5.50	3.70
Ignition loss (mainly water)	3.00	13.00	7.00

[1] Vitrified Paving Brick, by H. A. Wheeler, page 18.

Brick clay.—Brick clays are divided into those used for common and for pressed and ornamental brick. Red earthenware, such as flowerpots, is also made of brick clay. Clays suitable for the manufacture of common brick are located in every state and almost every county in the Union. Of all clays these are usually the most impure, often containing a rather high percentage of lime. Lime in a finely divided state is not harmful; but in the form of limestone pebbles it is very injurious to the finished product, as the process of burning converts these pebbles into quicklime, which is apt to slack, thus breaking the brick, upon being exposed to the atmosphere. This difficulty is sometimes overcome by passing the clay through a pulverizer, which crushes the pebbles, or by screening it to remove them. The following table shows the range of the constituents of clays used in the manufacture of common building brick, together with an average analysis of such clays:

Analysis of common brick clay.[1]

	Minimum (per cent).	Maximum (per cent).	Average (per cent).
Silica	34.35	90.877	49.27
Alumina	22.14	44.00	22.774
Ferric oxide	0.126	33.12	5.311
Lime	0.024	23.20	2.017
Magnesia	0.02	11.03	2.66
Alkalies	0.17	15.32	2.768
Water	0.05	13.60	5.749
Moisture	0.17	9.64	2.502

[1] New York State Museum, Bulletin No. 35, page 639.

Pressed brick and ornamental brick require a higher grade of clay, the buff varieties being made sometimes from a refractory or semirefractory clay. The buff color in refractory clay is due to the low percentage of iron; in other clays, notably the Milwaukee clay, from which is made, probably, the best known buff or cream brick, it is due to a large percentage of lime, which enters into chemical combination with the iron, thus neutralizing its coloring effect.

Slip clay.—Slip clay is used in glazing low grade products such as earthenware and stoneware. It must fuse at a low temperature and produce a glaze of even color. The clay generally used for this purpose is mined near Albany, N. Y., and hence is known as Albany slip. It produces a dark brown glaze, and is shipped to almost every state in the Union.

Paper clay.—Paper clay is used, as its name indicates, in the manufacture of paper. As clay used for this purpose is not molded or fired, plasticity, fusibility, and vitrifying qualities need not be considered; hence any pure white, smooth, gritless clay can be used. Where the clay is suitable in color, but gritty, the grit is sometimes washed out. In the United States paper clays are mined in Delaware, Georgia, Maryland, Pennsylvania, and Wisconsin.

The following is an analysis of so-called kaolin from Wisconsin, used in paper manufacture:

Analysis of paper clay from Wisconsin.[1]

	Per cent.
Silica	52.41
Alumina	34.10
Ferric oxide	0.15
Lime	0.05
Magnesia	0.12
Alkalies	0.64
Titanic oxide	0.80
Combined water	11.89
	100.16

[1] Wisconsin Geological and Natural History Survey, Bulletin No. 7, page 272.

Methods of mining.—There are several methods of mining clay, but only two are generally followed, viz, open pit and underground mining. Open pit mining is conducted in several ways—with pick and shovel, with a scraper, or by falling the clay, that is, by undermining it and letting it fall. Sometimes explosives are used for the last-named purpose.

In underground clay mining the methods of working are the same as those usually followed in coal mining, namely, by shaft or tunnel, with drifts, slopes, and chambers; there are, however, comparatively few deep mines in the clay industry, except where the clay is mined in connection with coal. Kaolin is sometimes mined by sinking through the vein a round shaft, the sides of which are timbered.

Preparation.—The commoner grades of clay are generally sold as mined, because to prepare them for the market in any way would add so greatly to their cost as to make them unprofitable. Even the common clays, however, are sometimes screened or ground to get rid of limestone pebbles or other small stones; screening removes them mechanically, while grinding overcomes their bad effects through comminution. In this country the common clays are not washed. The kaolins and ball clays are, however, sometimes washed at the mines, but they are again washed or prepared at the

pottery before being manufactured into white ware.[1] Another method of separating the clay from its undesirable impurities is by fans. This method can only be employed where the impurities are in the form of coarse particles or grains of sand, and consists in first grinding the clay to a very fine powder, after which it is carried to a flue through which a strong current of air is forced; this immediately carries the finer particles to the end of the flue where they are dropped into a bin. The coarser particles are dropped into the flue and carried back to the pulverizer to be ground over again. In the manufacture of pottery, and also of brick by the dry press process, the clay is cured, or weathered, often for months, before being used.

Uses.—Clay is used most extensively in the manufacture of common building brick; next in importance, as measured by the quantity of material consumed, is front or pressed brick, with its almost limitless variety in color and shape. Then there are vitrified brick, with a large and growing field of usefulness, and fire brick, the shape and utility of which are almost without limit, stove lining being an important subdivision. Other important products are drain tile, sewer pipe, ornamental terra cotta, fireproofing, roofing tile, flooring tile, and encaustic tile.

In addition there are assayers' supplies, boiler and locomotive tile and tank blocks, building blocks, burnt clay ballast, chemical brick, patent chimney brick, chimney pipes and tops, clay furnaces and retorts, conduits for underground wires, crucibles, cupola bricks, fence posts and fence post stubs, flue linings, frost proof cellar brick, gas logs and settings, glass-house furnace blocks, grave markers, muffles, porous cups, runner brick, sidewalk tile, souvenirs, stone pumps, terra cotta vases, tile mantels, wall coping, washboards, and well brick and tile.

In addition to the well-known pottery products of clay, such as red earthenware, stoneware, yellow and Rockingham ware, and the various grades of white ware from C. C. ware to china, the following wares also are made of clay: Acid proof tanks, art and chemical pottery, bath tubs, caster wheels, electrical supplies, faience glass pots, insulators, jardinieres, lavatories, pins, stilts and spurs for potters' use, porcelain hardware trimmings, shuttle eyes and thread guides, pump stands, and wash tubs.

[1] For description of methods of washing clays, see New York State Museum, Bulletin No. 35.

TABLE 7.—DETAILED

		United States.	Alabama.	California.	Colorado.	Delaware.	Georgia.	Illinois.
1	Number of mines	205	5	6	4	6	7	8
2	Number of operators	203	5	6	4	6	7	7
	Character of ownership:							
3	Individual	115	5	4	3	1	1	5
4	Firm	36					2	1
5	Incorporated company	52		2	1	5	4	1
	Salaried officials, clerks, etc.:							
6	Total number	185		4	3	13	19	2
7	Total salaries	$150,505		$3,558	$2,460	$12,740	$12,320	$1,200
	General officers—							
8	Number	50				6	13	
9	Salaries	$60,295				$6,000	$8,700	
	Superintendents, managers, foremen, surveyors, etc.—							
10	Number	94		3	1	6	6	1
11	Salaries	$67,492		$2,658	$930	$6,020	$3,620	$600
	Foremen below ground—							
12	Number	15			2			
13	Salaries	$8,761			$1,530			
	Clerks—							
14	Number	26		1		1		1
15	Salaries	$13,957		$900		$720		$600
	Wage-earners:							
16	Aggregate average number	2,433	33	17	50	169	136	42
17	Aggregate wages	$958,892	$9,634	$11,680	$32,642	$69,472	$37,333	$19,602
	Above ground—							
18	Total average number	2,039	33	17	14	102	136	36
19	Total wages	$779,181	$9,634	$11,680	$8,950	$43,819	$37,333	$17,075
	Engineers, firemen, and other mechanics—							
20	Average number	106	2			14	3	
21	Wages	$50,580	$525			$6,679	$1,354	
	Miners—							
22	Average number	1,358	25	13	11	51	58	21
23	Wages	$522,896	$7,813	$8,680	$7,030	$21,140	$15,555	$9,200
	Boys under 16 years—							
24	Average number	30					7	
25	Wages	$5,548					$1,124	
	All other wage-earners—							
26	Average number	545	6	4	3	37	68	15
27	Wages	$200,157	$1,296	$3,000	$1,920	$16,000	$19,300	$7,875
	Below ground—							
28	Total average number	394			36	67		6
29	Total wages	$179,711			$23,692	$25,653		$2,527
	Miners—							
30	Average number	291			19	22		4
31	Wages	$129,695			$12,108	$8,800		$1,840
	Miners' helpers—							
32	Average number	17			4			2
33	Wages	$8,611			$2,384			$687
	All other wage-earners [2]—							
34	Average number	86			13	45		
35	Wages	$41,405			$9,200	$16,853		
	Average number of wage-earners at specified daily rates of pay:							
	Engineers—							
36	$1.00 to $1.24	6						
37	$1.25 to $1.49	2						
38	$1.50 to $1.74	24	2			8	1	
39	$1.75 to $1.99	2						
40	$2.00 to $2.24	11				1		
41	$2.25 to $2.49	2						
42	$2.50 to $2.74	4					1	
43	$3.00 to $3.24	1						
44	$3.25 to $3.49	1						
	Firemen—							
45	$0.75 to $0.99	1					1	
46	$1.00 to $1.24	2						
47	$1.25 to $1.49	3						
48	$1.50 to $1.74	10				2		
49	$1.75 to $1.99	2						
50	$2.00 to $2.24	1						
	Machinists, blacksmiths, carpenters, and other mechanics—							
51	$1.00 to $1.24	7						
52	$1.25 to $1.49	5						
53	$1.50 to $1.74	12				2		
54	$2.00 to $2.24	8				1		
55	$2.25 to $2.49	1						
56	$2.50 to $2.74	1						
	Miners—							
57	$0.50 to $0.74	1						
58	$0.75 to $0.99	275			1		57	
59	$1.00 to $1.24	206	25					6
60	$1.25 to $1.49	730				68		10
61	$1.50 to $1.74	232				5	1	2
62	$1.75 to $1.99	84		6				
63	$2.00 to $2.24	76		5	2			7
64	$2.25 to $2.49	53			23			
65	$2.50 to $2.74	29		2	6			
66	$2.75 to $2.99	7			1			
67	$3.00 to $3.24	6						
	Miners' helpers—							
68	$1.25 to $1.49	2						2
69	$1.50 to $1.74	8						
70	$1.75 to $1.99	3						
71	$2.00 to $2.24	4			4			
	Timbermen and track layers—							
72	$0.75 to $0.99	2						
	Boys under 16 years—							
73	Less than $0.50	9					4	
74	$0.50 to $0.74	13					3	
75	$0.75 to $0.99	5						
76	$1.00 to $1.24	3						

[1] Includes operators distributed as follows: Connecticut, 1; Florida, 2; Indiana, 2; Massachusetts, 1; Michigan, 1; North Carolina, 3; Utah, 1; Vermont, 2; Washington, 1.

SUMMARY: 1902.

Kentucky.	Maryland.	Missouri.	New Jersey.	New York.	Ohio.	Pennsylvania.	South Carolina.	Tennessee.	Texas.	West Virginia.	Wisconsin.	All other states.[1]	
5	6	25	34	8	31	19	8	9	3	4	3	14	1
5	6	25	34	7	31	19	8	9	3	4	3	14	2
1	6	12	22	5	21	8	3	9	3	2	1	3	3
		11	3	2	5	8						4	4
4		2	9		5	3	5			2	2	7	5
4	1	20	35	5	13	22	14	4		1	2	23	6
$3,200	$300	$10,115	$26,044	$2,575	$8,580	$28,473	$11,300	$1,900		$720	$3,600	$21,420	7
2		3	7	1	5	7	2				1	3	8
$2,400		$3,990	$5,500	$225	$4,000	$17,000	$4,080				$2,400	$6,000	9
2		10	20	4	4	10	10	3			1	13	10
$800		$3,136	$14,875	$2,350	$2,760	$8,433	$6,680	$1,000			$1,200	$12,430	11
		4			2	4				1		2	12
		$1,961			$1,100	$2,560				$720		$800	13
	1	3	8		2	1	2	1				5	14
	$300	$1,028	$5,669		$720	$480	$540	$900				$2,100	15
48	21	120	702	14	120	312	198	46		41	36	328	16
$17,080	$4,556	$66,169	$293,232	$6,396	$58,818	$130,753	$45,448	$13,140		$25,022	$16,050	$101,865	17
48	21	78	702	14	65	248	198	46		14	34	233	18
$17,080	$4,556	$40,462	$293,232	$6,396	$28,133	$104,406	$45,448	$13,140		$6,156	$15,150	$76,531	19
2	1	1	17		6	16	10			3	4	27	20
$780	$360	$853	$9,000		$3,180	$9,120	$3,610			$1,594	$2,400	$11,125	21
43	16	40	667	13	49	143	131	23			19	35	22
$15,550	$3,181	$15,434	$276,717	$6,071	$18,990	$59,461	$29,147	$6,940			$8,550	$13,434	23
			5			1	8				2	7	24
			$1,184			$300	$1,160				$600	$1,180	25
3	4	37	13	1	10	88	49	23		11	9	164	26
$750	$1,012	$24,175	$6,331	$325	$5,963	$35,525	$11,531	$6,200		$4,562	$3,600	$50,792	27
		42			55	64				27	2	95	28
		$25,707			$30,685	$26,347				$18,866	$900	$25,334	29
		26			48	57				18	2	95	30
		$17,206			$26,744	$24,431				$12,332	$900	$25,334	31
		8			3								32
		$4,100			$1,440								33
		8			4	7				9			34
		$4,401			$2,501	$1,916				$6,534			35
1							3					2	36
						1	1						37
			1		1	3						8	38
						1	1						39
	1		2		2	1				2	2		40
		1			1								41
			1		1	1							42
			1										43
			1										44
													45
													46
1			2									2	47
			2			2						4	48
					1					1			49
											1		50
							3					4	51
			2			3							52
			3				2					5	53
			1			4					1	1	54
			1										55
												1	56
								1					57
		2					130					85	58
32	11	11	15		33	30	1	22				20	59
1	4	22	508	6	15	96							60
10		10	77	4	15	61				1	21	25	61
	1		20	1	6								62
		8	21	2	21	10							63
		4			6	3				17			64
		3	20		1								65
		6											66
			6										67
													68
		8											69
					3								70
													71
								2					72
							5						73
							3					7	74
			5										75
						1					2		76

[1] Includes timbermen and track layers.

TABLE 7.—DETAILED

		United States.	Alabama.	California.	Colorado.	Delaware.	Georgia.	Illinois.
	Average number of wage-earners at specified daily rates of pay—Con.							
	All other wage-earners—							
77	Less than $0.50	2						
78	$0.50 to $0.74	30						
79	$0.75 to $0.99	47	6				39	
80	$1.00 to $1.24	270					29	
81	$1.25 to $1.49	129				78		
82	$1.50 to $1.74	36				1		
83	$1.75 to $1.99	48				2		15
84	$2.00 to $2.24	21		1	6			
85	$2.25 to $2.49	9						
86	$2.50 to $2.74	34		3	10	1		
87	$3.00 to $3.24	3						
	Average number of wage-earners employed during each month:							
	Men 16 years and over—							
88	January	2,119	25	13	52	106	114	44
89	February	2,100	25	13	52	108	112	42
90	March	2,281	31	16	54	143	114	40
91	April	2,405	28	21	54	189	120	43
92	May	2,575	32	21	51	195	142	42
93	June	2,624	32	20	51	197	145	42
94	July	2,604	37	20	51	176	168	41
95	August	2,568	36	20	51	185	107	41
96	September	2,480	39	19	48	181	106	41
97	October	2,472	39	15	48	195	135	42
98	November	2,393	36	15	44	190	139	42
99	December	2,265	36	11	44	168	146	44
	Boys under 16 years—							
100	January	28					7	
101	February	28					7	
102	March	28					7	
103	April	28					7	
104	May	33					7	
105	June	34					7	
106	July	34					7	
107	August	33					7	
108	September	32					7	
109	October	27					7	
110	November	27					7	
111	December	28					7	
	Contract work:							
112	Total cost	$13,241			$7,450			
113	Number of employees	36			13			
	Miscellaneous expenses:							
114	Total	$126,873	$3,866	$1,656	$7,637	$19,590	$3,017	$1,999
115	Royalties and rent of mine and mining plant	$59,387	$3,785	$1,656	$7,314	$8,589	$100	$1,035
116	Rent of offices, taxes, insurance, interest, and other sundries	$67,486	$81		$323	$11,001	$2,917	$964
117	Cost of supplies and materials	$272,823	$1,993	$910	$5,608	$27,235	$15,500	$3,916
	Product:[1]							
118	Quantity, short tons	1,455,357	40,065	23,483	75,913	123,319	18,595	52,152
119	Value	$2,061,072	$19,742	$24,445	$67,434	$171,714	$76,480	$38,463
	Power owned:							
120	Total horsepower	4,478	10			353	99	76
	Engines—							
	Steam—							
121	Number	98	1			9	3	3
122	Horsepower	3,942	10			345	90	76
	Gas or gasoline—							
123	Number	2				1		
124	Horsepower	18				8		
	Water wheels—							
125	Number	1						
126	Horsepower	25						
	Other power—							
127	Number	22					9	
128	Horsepower	493					9	

[1] Includes 39,157 tons of sand, valued at $35,956, produced in connection with the mining of clay. Of this amount 7,120 tons, valued at $9,320, were mined in Ohio, and 32,037 tons, valued at $26,636, in Pennsylvania.

SUMMARY: 1902—Continued.

Kentucky.	Maryland.	Missouri.	New Jersey.	New York.	Ohio.	Pennsylvania.	South Carolina.	Tennessee.	Texas.	West Virginia.	Wisconsin.	All other states.	
.....	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	77
.....	.....	.....	.....	.....	.....	.....	30	.....	.....	.....	.....	.....	78
2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	79
1	1	1	.....	.....	.....	46	14	18	.....	2	.....	158	80
.....	1	3	1	1	1	32	3	.....	.....	3	6	.....	81
.....	.....	3	7	.....	.....	7	.....	3	.....	6	3	6	82
.....	.....	11	5	.....	12	2	.....	.....	.....	1	.....	.....	83
.....	.....	8	.....	.....	.....	4	2	.....	.....	.....	.....	.....	84
.....	.....	.....	.....	.....	1	.....	.....	.....	.....	8	.....	.....	85
.....	.....	19	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	86
.....	.....	.....	.....	.....	.....	3	.....	.....	.....	.....	.....	.....	87
46	14	115	591	5	84	277	198	43	.....	39	9	344	88
46	14	112	590	5	94	274	193	43	.....	39	9	334	89
47	20	109	617	5	105	305	203	43	.....	40	9	330	90
52	21	99	699	6	125	310	211	43	.....	40	14	330	91
51	23	117	762	8	132	319	216	38	.....	41	61	324	92
59	23	119	777	13	131	338	210	38	.....	40	69	320	93
53	23	118	798	17	127	331	169	34	.....	42	76	323	94
60	22	125	787	31	146	337	167	52	.....	42	66	293	95
46	23	128	754	32	149	321	172	52	.....	41	36	292	96
41	24	131	691	29	136	316	182	56	.....	43	25	324	97
41	24	138	662	11	111	311	182	65	.....	42	24	316	98
34	21	129	636	6	100	293	177	45	.....	43	10	322	99
.....	.....	.....	4	.....	.....	1	8	.....	.....	.....	.....	8	100
.....	.....	.....	4	.....	.....	1	8	.....	.....	.....	.....	8	101
.....	.....	.....	4	.....	.....	1	8	.....	.....	.....	.....	8	102
.....	.....	.....	4	.....	.....	1	8	.....	.....	.....	.....	8	103
.....	.....	.....	5	.....	.....	1	8	.....	.....	.....	4	8	104
.....	.....	.....	5	.....	.....	1	8	.....	.....	.....	6	7	105
.....	.....	.....	6	.....	.....	1	8	.....	.....	.....	5	7	106
.....	.....	.....	6	.....	.....	1	8	.....	.....	.....	5	6	107
.....	.....	.....	6	.....	.....	1	8	.....	.....	.....	4	6	108
.....	.....	.....	5	.....	.....	1	8	.....	.....	.....	.....	6	109
.....	.....	.....	5	.....	.....	1	8	.....	.....	.....	.....	6	110
.....	.....	.....	6	.....	.....	1	8	.....	.....	.....	.....	6	111
$4,000	.....	$77	.....	.....	$1,414	$300	.....	.....	.....	.....	.....	.....	112
15	.....	3	.....	.....	4	1	.....	.....	.....	.....	.....	.....	113
$1,546	$256	$11,704	$19,403	$1,087	$7,072	$13,825	$3,185	$3,745	$150	$1,618	$1,225	$24,292	114
$897	$245	$6,264	$6,939	$400	$3,476	$6,445	.....	$60	.....	.....	$877	$11,305	115
$649	$11	$5,440	$12,464	$687	$3,596	$7,380	$3,185	$3,685	$150	$1,618	$348	$12,987	116
$10,250	$580	$11,123	$67,476	$1,056	$12,346	$42,349	$11,612	$767	.....	$10,421	$3,092	$46,589	117
26,562	8,882	121,401	494,800	8,909	142,440	161,546	29,136	14,050	310	57,506	2,735	52,953	118
$44,256	$10,055	$134,862	$612,721	$14,535	$101,305	$288,811	$107,325	$27,171	$455	$48,266	$23,178	$254,854	119
10	50	186	383	6	293	1,338	353	20	.....	236	115	950	120
1	.....	6	16	6	6	16	8	2	.....	4	3	14	121
10	.....	132	383	6	293	1,088	313	20	.....	236	115	825	122
.....	.....	.....	.....	.....	.....	1	.....	.....	.....	.....	.....	.....	123
.....	.....	.....	.....	.....	.....	10	.....	.....	.....	.....	.....	.....	124
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1	125
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	25	126
.....	1	2	.....	.....	.....	5	2	.....	.....	.....	.....	3	127
.....	50	54	.....	.....	.....	240	40	.....	.....	.....	.....	100	128

ABRASIVE MATERIALS

ABRASIVE MATERIALS.

By Joseph Hyde Pratt.

The mining of abrasive materials forms a very important industry among the minor minerals, on account of their close connection with all manufacturing industries. As a whole, these abrasive materials are but little understood, although they are of widespread use. No manufacturing plant, machine shop, blacksmith shop, farm, or household is without some form of abrasive, so that these materials are perhaps in as universal use as any group of minerals. While the abrasive materials vary widely in character and occurrence, they can readily be grouped together and considered under one head on account of the similarity of their use. The natural products that are used for abrasive purposes are as follows: Buhrstones and millstones (conglomerate and granite); corundum and emery; crystalline quartz; garnet; grindstones and pulpstones (sandstone); infusorial earth, tripoli, and pumice; and oilstones, whetstones, and scythestones (sandstone and schist).

The crystalline quartz included in this report is used in the manufacture of sandpaper, scouring soaps, wood-finishing materials, etc., and does not include that used in the pottery and glass industries, and which is included in the report on flint and feldspar. On the other hand, the entire production of infusorial earth and tripoli is included in these statistics because the small production of these materials, although but little is actually used for abrasive purposes, does not justify separate treatment.

In treating these mineral products under the one subject of abrasives it is not always feasible to give detailed statistics regarding each, as would be done if they were treated separately, and proper comparisons between expenditures on account of the production of the different abrasives can not always be made, because some of the articles require more elaborate processes than others in their preparation for market. At none of the previous censuses have the abrasive materials been grouped as they are in this report. The statistics of mining operations for some of these minerals were reported for 1880 and 1889, but they were not brought together in a single class.

At the census of 1880 the classifications of abrasives were, corundum (emery), garnet, infusorial earth, oilstones, scythestones, and whetstones. At the Eleventh Census the classifications were, corundum, grindstones, infusorial earth, millstones, and whetstones.

In Table 1 are given the statistics for these several classifications for the censuses of 1902 and 1889, and while not comparable, yet they indicate in some measure the growth in the production of abrasive materials for this period. For corundum and emery, and also for oilstones, whetstones, and scythestones, comparisons of most of the items can be made for the two censuses.

Buhrstones and millstones to the value of $1,425, included in the statistics for 1902, were quarried at granite quarries; grindstones and pulpstones to the value of $403,066, and oilstones, whetstones, and scythestones to the value of $38,612 at sandstone quarries; and infusorial earth, tripoli, and pumice to the value of $1,436 at talc and soapstone mines, all as by-products. In these cases the wages and other expenses of production are included in the statistics for granite, sandstone, and talc and soapstone, respectively.

The production of certain of these abrasives is on the decline, while that of others is increasing, but because of the increase in manufacturing industries the aggregate amount of abrasive materials used in the United States is greater than ever before. As their use is limited there could easily be an overproduction of most of them, but in the aggregate there will be an increasing demand from year to year. This will depend principally upon the growth of our manufacturing industries and the development of our agricultural lands, and with an increase or a decrease in manufacturing especially there will be a corresponding change in the production of abrasives. The principal change, however, that will be noticed is in the amount of the different kinds of abrasives used from year to year, the production of some increasing rapidly, others steadily decreasing, these variations being due to the introduction of new natural or artificial abrasive products, to changes in methods of manufacturing, and to the use of new types of machinery, affecting principally the abrasives formerly used for agricultural implements.

TABLE 1.—COMPARATIVE SUMMARY: 1902 AND 1889.

	Year.	All abrasives.	Buhrstones and millstones.	Corundum and emery.	Crystalline quartz.	Garnet.	Grindstones and pulpstones.	Infusorial earth, tripoli, and pumice.	Oilstones, whetstones, and scythestones.
Number of mines or quarries	1902	82	29	5	6	7	9	11	15
	[1]1889	.....	.....	.....	.....	.....	.....	.....	.....
Number of operators	1902	75	29	5	5	7	9	10	10
	[1]1889	.....	.....	.....	.....	.....	.....	.....	.....
Salaried officials, clerks, etc.: Number	1902	75	7	9	8	12	25	8	6
	1889	(1)	(1)	(2)	(1)	(1)	(3)	(1)	(1)
Salaries	1902	$48,008	$4,682	$5,960	$6,030	$9,178	$13,042	$4,016	$5,100
	1889	(1)	(1)	(2)	(1)	(1)	(3)	(1)	(1)
Wage-earners: Average number	1902	610	86	47	29	118	210	35	85
	1889	370	[4]98	[4]129	(1)	(1)	(3)	[4]52	[4]91
Wages	1902	$296,914	$39,562	$32,871	$13,592	$59,632	$99,598	$13,682	$37,977
	1889	$92,812	$17,853	$44,650	(1)	(1)	(3)	$8,388	$21,911
Contract work	1902	.....	.....	.....	.....	.....	.....	.....	.....
	1889	$3,168	$1,193	$600	(1)	(1)	(3)	$575	$800
Miscellaneous expenses	1902	$42,410	$1,480	$2,779	$1,950	$4,952	$24,433	$2,263	$4,553
	1889	$10,597	$925	$2,462	(1)	(1)	(3)	$6,955	$255
Cost of supplies and materials	1902	$80,309	$1,809	$25,114	$950	$10,123	$31,349	$2,297	$7,662
	1889	$12,394	$1,413	$9,383	(1)	(1)	(3)	$760	$838
Product: Quantity, short tons	1902	.....	[5]6,667	4,251	15,104	3,926	55,657	6,415	3,876
	1889	.....	(1)	2,245	(1)	(1)	(3)	3,466	2,991
Value	1902	[6]$1,177,711	$59,808	$104,605	$43,085	$132,820	$667,431	$55,994	$113,968
	1889	$636,659	$35,155	$105,565	(1)	(1)	$439,587	$23,372	$32,980

[1] Not reported.
[2] Included in wage-earners and wages.
[3] Included with statistics for sandstone.
[4] Includes foremen; their salaries are included in wages.
[5] Number of pieces.
[6] The United States Geological Survey reports $1,326,755, which includes products finished elsewhere than at the quarry.

During the past fifteen years, many experiments and investigations have been made with a view of producing artificial abrasives that would be equal to or superior to the natural products. As a result of these experiments there are now four artificial abrasives on the market—carborundum, crushed steel, alundun (artificial corundum), and adamite. The value of the artificial abrasives produced and used in the United States during 1902 was over $300,000, and will illustrate the extent to which these artificial products are being utilized at the expense of natural products.

As shown by Table 1, of the 82 mines or quarries producing abrasive materials in 1902, 29 are credited to buhrstones and millstones, this being due not to the large production of this type of abrasive, but to the fact that there were a great many individual operators in the New York field producing a small number of buhrstones. Grindstones and pulpstones are credited with only 9 mines or quarries, although the value of their production is greater than the value of the combined production of all the other abrasives.

These 82 mines or quarries were worked by 75 operators, there being 39 individuals, 17 firms, and 19 incorporated companies. Twenty-three of the 39 individual operators were producers of buhrstones and millstones. The next largest number of individual operators were the 7 producing oilstones and whetstones.

There were 35 mines or quarries that have produced abrasive materials of some kind during the past few years from which no production was reported for 1902. These were distributed among 16 states, from Maine to California. Nineteen were owned by individuals, 11 by firms, and 5 by incorporated companies. The capital stock issued by the incorporated companies amounted to $258,000, all of which was reported for the corundum and emery industry. While some of these idle plants may have shut down permanently, others will probably be producers again in another year or two. Development work, without production, was reported by 1 corundum and emery mine.

Capital stock of incorporated companies.—No definite comparisons can be made of the statistics of the incorporated companies producing abrasives, for the reason that the corporations are not always confined simply to the production of an abrasive material. Thus, in the case of the grindstone industry, the companies producing the greater amount of this abrasive are also producers of building stone, which is their principal product, the manufacture of the grindstones being the smaller part of their business. The details of their capitalization are, therefore, given under sandstones in the report on "Stone."

In Table 2 are given the details of the capitalization of the 19 incorporated companies producing abrasives.

TABLE 2.—CAPITALIZATION OF INCORPORATED COMPANIES, BY KINDS OF ABRASIVES: 1902.

	All abrasives.	Corundum and emery.	Crystalline quartz.	Garnet.	Grindstones and pulpstones.	Infusorial earth, tripoli, and pumice.	Oilstones, whetstones, and scythestones.
Number of incorporated companies	19	4	2	3	5	3	2
Capital stock and bonds issued	$5,545,900	$2,365,800	$300,000	$2,412,000	$253,100	$130,000	$85,000
Capital stock:							
Total authorized—							
Number of shares	371,551	333,000	15,000	18,620	2,531	1,300	1,100
Par value	$6,235,100	$3,600,000	$300,000	$1,862,000	$253,100	$130,000	$90,000
Total issued—							
Number of shares	305,309	266,858	15,000	18,620	12,531	1,300	1,000
Par value	$4,565,900	$1,935,800	$300,000	$1,862,000	$253,100	$130,000	$85,000
Dividends paid	$30,860	$10,860	$10,000	.....	.....	$10,000	.....
Common—							
Authorized—							
Number of shares	366,051	328,000	15,000	18,620	2,031	1,300	1,100
Par value	$5,685,100	$3,100,000	$300,000	$1,862,000	$203,100	$130,000	$90,000
Issued—							
Number of shares	302,749	264,798	15,000	18,620	2,031	1,300	1,000
Par value	$4,309,900	$1,729,800	$300,000	$1,862,000	$203,100	$130,000	$85,000
Dividends paid	$20,000	.....	$10,000	.....	.....	$10,000	.....
Preferred—							
Authorized—							
Number of shares	5,500	5,000	.....	.....	500	.....	.....
Par value	$550,000	$500,000	.....	.....	$50,000	.....	.....
Issued—							
Number of shares	2,560	2,060	.....	.....	500	.....	.....
Par value	$256,000	$206,000	.....	.....	$50,000	.....	.....
Dividends paid	$10,860	$10,860	.....	.....	.....	.....	.....
Bonds:							
Authorized—							
Number	1,140	540	.....	600	.....	.....	.....
Par value	$1,070,000	$470,000	.....	$600,000	.....	.....	.....
Issued—							
Number	1,050	500	.....	550	.....	.....	.....
Par value	$980,000	$430,000	.....	$550,000	.....	.....	.....
Interest paid	$24,000	$24,000	.....	.....	.....	.....	.....

The total par value of the capital stock and bonds issued by the incorporated companies was $5,545,900. The tendency toward incorporation is most evident in the companies mining garnet and corundum and emery, but the capitalization reported for these companies includes also, in part, the amount utilized for the subsequent manufacturing process. These industries, too, are the only ones reporting a bonded indebtedness. Four companies producing corundum and emery reported a capital stock and funded debt amounting to $2,365,800, and three companies producing garnet reported $2,412,000 for the same items. No incorporated companies were reported as engaged in producing buhrstones and millstones.

Crystalline quartz; grindstones and pulpstones; infusorial earth, tripoli, and pumice; and oilstones, whetstones, and scythestones show a comparatively small average capitalization. Dividends amounting to $10,000 were paid on the common stock of crystalline quartz companies, and a like amount on the common stock of companies producing infusorial earth, tripoli, and pumice. Companies producing corundum and emery paid the sum of $10,860 as dividends on preferred stock, and $24,000 as interest on bonds having a par value of $430,000.

Employees and wages.—The total average number of employees engaged in the abrasive industry during 1902 was 685, of whom 75, or 10.9 per cent, were salaried employees, and 610, or 89.1 per cent, wage-earners. These received in salaries and wages $344,922, of which $48,008 was received by the salaried employees and $296,914 by the wage-earners. The classification of these salaried employees and wage-earners is shown in Tables 4 and 5.

Of the 610 wage-earners, only 25, or 4.1 per cent, were employed below ground, and of this number 22 were employed in the corundum and emery industry. The other 3 wage-earners below ground were engaged in the infusorial earth industry. All the other abrasives are obtained by means of open cuts and pits. Because of this the operations are of necessity somewhat curtailed during the winter months. As is seen in Table 4, the monthly average number of wage-earners employed during January, February, and March ranged from 429 to 478, while during the remaining months of the year the range was from 596 to 703. The daily rates of pay of the wage-earners, also shown in Table 4, varied from 75 cents to $4.24, the lowest wages being paid principally to the miners or quarrymen and the highest to the engineers and machinists.

Of all the wage-earners, 212, or 34.8 per cent, received from $1.50 to $1.74 per day, and of these, 160, or 75.5 per cent, were miners or quarrymen. Twenty-six per cent of the wage-earners received less than $1.50 per day. Of the total number 6.5 per cent were classified as engineers, of whom the greater number received from $2 to $2.24 per day; 402, or 65.9 per cent, were returned as miners, their wages varying from 75 cents to $3.24 per day. Only 10 miners' helpers were reported, but it is very probable that the actual number of this class of wage-earners was considerably in excess of this figure, since many of them were included under "all other wage-earners." It will be noticed that in this industry the question of child labor

is unimportant, as only 3 boys under 16 years were employed.

Supplies, materials, and miscellaneous expenses.—The total cost of the supplies and materials used in the mining and quarrying of the abrasive materials produced in 1902 was $80,309. Of this amount, $31,349, or 39 per cent, was used in the grindstone industry, and $26,114, or 32.5 per cent, in the corundum and emery industry.

The miscellaneous expenses amounted to $42,410, of which $8,421 was paid out for royalties and rent of mine and mining plant, and $33,989 for rent of offices, taxes, insurance, interest, and other sundries.

Mechanical power.—Of the primary power reported, 2,300 horsepower, or 92.2 per cent, was steampower applied by 71 steam engines. Forty-one steam engines, having a total of 1,235 horsepower, were used in the grindstone and pulpstone industry. The next largest number of steam engines, 13, was reported for the oilstone, whetstone, and scythestone industry, but these aggregated only 185 horsepower, while the 7 steam engines used in the garnet industry aggregated 420 horsepower, and the 7 in the infusorial earth, tripoli, and pumice industry had a total of 410 horsepower. Eighty-eight horsepower was generated by 7 gas or gasoline engines, of which 3, having a capacity of 80 horsepower, were used in the corundum and emery industry, and 4, having 8 horsepower, in the oilstone, whetstone, and scythestone industry. In addition there was 1 electric motor, having a capacity of 5 horsepower; this was used in the infusorial earth, tripoli, and pumice industry.

Production.—The value of the production was $1,177,711, an increase of $541,052 over the value reported for 1889, which was $636,659. Of the particular abrasives, grindstones and pulpstones show the largest increase, $227,844 in value, over the production of 1889. The second largest increase was in oilstones, whetstones, and scythestones, the value of which was $113,968 in 1902, an increase of $80,988.

Oilstones and whetstones are not always finished at the quarries, but are in some instances shipped to a central plant and there prepared for use. When the finishing process is not conducted immediately in connection with the actual quarrying, the value of the crude product is given in Census reports. In the reports of the United States Geological Survey, on the other hand, the finished value is given, for the reason that, with the exception of Arkansas novaculite, this material would not be marketable in its crude state. Were the finished value to be taken in every instance by the Bureau of the Census, the total product for oilstones, whetstones, and scythestones would be increased by $107,794, and the production would rank as second instead of third among abrasive materials.

In order to show comparatively the value of the annual consumption of each abrasive used in the United States, the value of the domestic product and of the imports reported since 1880 are given in the following table. The statistics are compiled from tables of the United States Geological Survey published in "Mineral Resources of the United States."

TABLE 3.—ABRASIVE MATERIALS—VALUE OF DOMESTIC PRODUCTS AND IMPORTS, BY KINDS: 1880 TO 1902.

[United States Geological Survey, "Mineral Resources of the United States."]

YEAR.[1]	ALL ABRASIVES.		BUHRSTONES AND MILLSTONES.		CORUNDUM AND EMERY.		CRYSTALLINE QUARTZ.[2]	GARNET.[2]	GRINDSTONES AND PULPSTONES.		INFUSORIAL EARTH, TRIPOLI, AND PUMICE.		OILSTONES, WHETSTONES, AND SCYTHESTONES.	
	Value of domestic product.	Value of imports.	Value of domestic product.	Value of imports.	Value of domestic product.	Value of imports.	Value of domestic product.	Value of domestic product.	Value of domestic product.	Value of imports.	Value of domestic product.[3]	Value of imports.[4]	Value of domestic product.	Value of imports.
1880	$782,880	$321,425	$200,000	$125,072	$29,280	$105,894	.....	.....	$500,000	$76,274	$45,600	.....	[5] $8,000	$14,185
1881	748,580	305,103	150,000	103,912	80,000	97,432	.....	.....	500,000	87,128	10,000	.....	8,580	16,631
1882	998,000	827,836	200,000	104,034	80,000	93,695	.....	.....	700,000	97,225	8,000	.....	10,000	27,832
1883	865,000	295,205	150,000	73,685	100,000	85,490	.....	.....	600,000	105,852	5,000	.....	10,000	30,178
1884	845,000	307,789	150,000	46,100	108,000	148,890	.....	.....	570,000	86,286	5,000	.....	12,000	26,513
1885	728,000	182,290	100,000	35,477	108,000	74,800	.....	.....	500,000	50,579	5,000	.....	15,000	21,434
1886	527,190	211,863	140,000	29,935	116,190	121,638	.....	.....	250,000	39,149	6,000	.....	15,000	21,141
1887	463,400	166,621	100,000	24,007	108,000	68,209	.....	.....	224,400	50,312	15,000	.....	16,000	24,093
1888	479,920	237,905	81,000	37,228	91,620	118,246	.....	.....	281,800	51,755	7,500	.....	18,000	30,676
1889	636,661	344,970	35,155	40,884	105,567	218,966	.....	.....	439,587	57,720	23,372	.....	[6] 32,980	27,400
1890	683,264	239,931	23,720	33,995	89,395	123,367	.....	.....	450,000	45,115	50,240	.....	69,909	37,454
1891	754,918	151,713	16,587	24,039	90,280	71,302	.....	.....	476,113	21,028	21,988	.....	150,000	35,344
1892	667,346	249,281	23,417	34,186	181,300	120,623	.....	.....	272,244	61,052	43,655	.....	146,730	33,420
1893	655,506	242,898	16,639	30,261	142,325	127,767	.....	.....	338,787	59,569	22,582	.....	135,173	25,301
1894	590,342	169,419	13,887	18,087	95,936	71,973	$18,054	$90,660	223,214	52,688	11,718	.....	136,873	26,671
1895	633,011	240,069	22,542	20,316	106,256	133,038	27,000	95,050	205,768	54,276	20,514	.....	155,881	32,439
1896	703,406	291,979	22,567	26,965	113,246	148,231	18,000	68,877	326,826	66,195	26,792	.....	127,098	50,588
1897	776,272	237,468	25,932	22,956	106,574	130,531	22,500	80,853	368,058	49,496	22,385	.....	149,970	34,485
1898	1,098,784	251,227	25,934	23,999	275,064	133,399	23,990	86,850	489,769	62,973	16,691	.....	180,486	30,856
1899	1,225,211	274,374	28,115	18,881	150,600	157,131	39,000	98,325	675,586	63,852	25,302	.....	208,283	34,510
1900	1,208,073	400,307	32,858	28,904	102,715	239,506	40,705	123,475	710,026	92,581	24,207	.....	174,087	39,316
1901	1,194,772	490,712	57,179	42,187	146,040	294,999	41,500	158,100	580,703	88,871	52,950	.....	158,300	64,655
1902	[6] 1,326,755	426,736	59,808	16,158	104,605	214,842	84,385	132,820	667,431	76,906	55,994	$62,374	221,762	56,456

[1] The value of imports is for fiscal years up to 1886; subsequent years are calendar years.
[2] Figures for imports, and figures for domestic product prior to 1894, not available.
[3] Prior to 1902 no value for pumice is included in these figures.
[4] Figures not available except for 1902.
[5] Value of unfinished product was reported for 1880 and 1889.
[6] Including $107,794 for finished oilstones, whetstones, and scythestones, and $41,250, the value of quartz, ground, not shown in Census tables.

The value of imports of all abrasives for 1902, $426,736, is 32.2 per cent of the value of the domestic production. The combined value of the domestic production and imports for 1902 was $1,753,491, which is greater than the combined value reported for any other year. In many cases the market value of abrasives is less at the present time than it was ten or twenty years ago, so that the values given represent a greater tonnage now than then.

Of the total value of the imports in 1902, $214,842, or 50.3 per cent, was for corundum and emery, the domestic production of this abrasive being a little less than one-half this value, or only $104,605. The year in which the combined value of the domestic production and imports of corundum and emery was greatest was 1901, when it amounted to $441,039. In that year the value of these imports was greater than during any other year on record, being $294,999, or $80,157 more than in 1902. The year when the value of the domestic production was greatest was 1898, when it amounted to $275,064. The value of the domestic production in 1902, $104,605, was less than that of thirteen of the years recorded. The selling price of corundum and emery varies from 1 to 10 cents per pound.

The class of abrasives ranking next in value of imports is grindstones and pulpstones, for which the imports in 1902 amounted to $76,906, or 18 per cent of the total value of all imports. This is, however, only 11.5 per cent of the total value of the domestic production of grindstones, which was $667,431. A large proportion of the value reported for the imports of grindstones was for pulpstones, from Newcastle-upon-Tyne, England, which are considered to be superior in some respects to those made from the Ohio sandstone. The American stone, however, is giving good satisfaction, which should ultimately cause a decrease in the imports of these pulpstones. The combined value of the imports and domestic production of grindstones and pulpstones was greatest in 1900, when it amounted to $802,607, being $58,270 more than the combined value for 1902, $744,337. The value of the domestic production was greatest in 1900, when it amounted to $710,026, which is $42,595 more than the value of the 1902 production. The next highest value, $700,000, was reached in 1882. It must, however, be taken into consideration that the tonnage of the production during the past ten years was much greater than in 1882, for in that year grindstones were worth about $15 per ton, while now they are sold at from $8 to $10 per ton.

The value of the domestic production of buhrstones and millstones in 1902, $59,808, was greater than that for any year since 1888; while the value of the imports, $16,158, was less than for any year recorded. The combined value of the imports and domestic production in 1902 was $75,966, which is $249,106 less than that of the year of greatest value, 1880, when the figures were $325,072. In that year the value of the imports was also greatest, amounting to $125,072, and the value of the domestic production, $200,000, was only equaled by one other year, 1882. This enormous decrease in the value of buhrstones used in the United States is due largely to the introduction of the roller mill process for grinding wheat. The increase in the domestic production since 1889 is due to the utilization of buhrstones in grinding the coarser cereals, mineral paints, etc., and, as the American stone answers as well for this purpose as the foreign, the continued falling off in the value of the imports is thus partially accounted for.

The combined value of the imports and domestic production of infusorial earth, tripoli, and pumice in 1902 was $118,368, of which $62,374, or over one-half, was the value of the imports. The value of the pumice imported was eight times the value of that produced in this country, while the value of the imports of infusorial earth was only three-fourths the value of the domestic production. It will be noticed that the domestic production of infusorial earth varies very widely from year to year, this being due to its limited use and also to the fact that some producers will mine in one year a quantity sufficient to last them two or more years. The small production of domestic pumice compared to the quantity imported is due to the distance of the domestic deposits from the large markets, which makes it impossible to compete with the pumice imported from the island of Lipari, Italy.

For oilstones, whetstones, and scythestones the combined value of the domestic production and imports for 1902, $278,218, was greater than that for any year since these statistics have been collected. The value of the domestic production for 1902, $221,762, was greater than that of any other year recorded, and was nearly four times the value of the imports for that year of $56,456. The year in which the value of imports was greatest was 1901, when it was $64,655, this being $8,199 more than the value of the imports of 1902. The almost constant increase in the oilstone industry is well illustrated in Table 3. The value of the domestic production has increased from $150,000 in 1891 to $221,762 in 1902. In the same time the imports have increased from $35,344 to $56,456. Prior to 1891 the statistics of the value of the domestic production represented the value of rough, crude rock, while since then it has been principally for the finished oilstone.

There have been no imports recorded of garnet or of crystalline quartz, but in the value of the domestic production of each there has been a general increase. The year of largest production of garnet was in 1901, when the product was valued at $158,100, this being $25,280 more than the value of the production of 1902, $132,820, which was the next highest value recorded. The increase in the value of crystalline quartz used for

abrasive purposes has been very marked, and, with the exception of 1896, the value each year has been greater than that of the year before.

The state in which the greatest value of abrasive materials was produced during 1902 is Ohio, the value being $587,284. The abrasive was principally grindstones, the value of which was $560,412, the balance being oilstones and whetstones. New York was second, with a value of $189,345, the abrasives produced in their order of production being garnet, emery, buhrstones, crystalline quartz, and tripoli.

The detailed statistics of abrasive materials for 1902 are given by states in Table 4 and by classes in Table 5.

DESCRIPTIVE.

The natural abrasive materials can readily be divided into two general groups:

1. Those which occur as rock formation and are cut and manufactured directly into the form desired, while retaining their original rock structure and appearance, as grindstones and whetstones.

2. Those which occur as a constituent of either a rock or a vein, and have to be mechanically separated from the associated gangue and cleaned, as corundum, emery, and garnet.

The artificial products would make a third class of abrasive materials, including carborundum, crushed steel, etc.

The abrasive materials are so universally distributed that there are but few localities where some of them may not be found. While this is the case, various kinds of abrasives are constantly being exported from and imported into the different countries on account either of their superior abrasive efficiency or of their better adaptability to required purposes.

The use of any particular abrasive is dependent upon the character of the abrasion to be accomplished. Thus, while the efficiency of a certain abrasive, as an abrasive, may be greater than that of another, it will not do as satisfactory work as one with less abrasive efficiency. For instance, although corundum has the highest abrasive efficiency of any included in the second type of abrasives mentioned, there are a number of cases where garnet, with a much lower abrasive efficiency, will give better satisfaction.

Grindstones.—The abrasive that is perhaps the most familiar to all is the grindstone. This is produced at the present time in commercial quantities in Michigan, Ohio, and West Virginia, and in much smaller quantities in Montana and Wyoming. The largest quantities are quarried in Ohio, whence the product is shipped to all parts of the United States. The quarries in the northern part of Ohio are located at Chagrin Falls, Berea, Cuyahoga Falls, Elyria, Euclid, Grafton, Independence, Massillon, North Amherst, Oberlin, and Peninsula; those in the eastern part of the state at Empire, Freeport, and Tippecanoe; and those in the southern portion of the state at Amesville, Belpre, Briggsdale, Constitution, Federal, Gravel Bank, Portsmouth, Vincent, and Marietta. A large number of the quarries in northern and southern Ohio have been brought under one management. At Empire, Peninsula, and Tippecanoe the pulpstone variety of grindstone is found; at the quarries at Empire pulpstone is the chief production, the regular grindstone forming but a very small part of the output.

In Michigan there was but one locality in 1902 producing grindstones—that near Grindstone City—but the state ranked next to Ohio in the value of its product.

The quarries in West Virginia are directly across the Ohio river from those in southern Ohio, and are located at Atlantic, Bois, Briscoe, Lonecedar, and Sherman.

Grindstones in very small quantity have been made for local use near Columbus, Yellowstone county, Mont.; near Rawlins, Carbon county, Wyo.; and near Edgemont, S. Dak.; but from the latter locality there was no production in 1902.

There is considerable variation in grindstones, dependent upon the variation of the sandstone from which they are made, which is due (1) to the character of the cementing material—whether it is a hydrous iron oxide, calcium carbonate, or silica; (2) to the percentage of the cementing material—that is, whether the grains are separated from each other by simply a minute film of cementing material or by a considerable layer; (3) to the size and shape of the grains of quartz. According to these variations, there are at least seven grits that are recognized as distinctive, six of which are derived from various grades of Ohio sandstone and one from the Michigan stone. These grits are as follows:

1. The Berea grit, which is a fine, sharp grit, used especially for sharpening edge tools, such as farmers' tools and woodworkers' small tools.

2. The Amherst grit, which is soft and loose, medium and loose, and fine. It is used especially for edge tools, saws, etc., in manufacturing establishments where the grindstone is propelled by steam.

3. The Independence grit, which is a coarse, sharp grit, is used for grinding springs and files and for the dry grinding of castings.

4. The Massillon grit, a coarse, sharp grit, used for grinding large edge tools, springs, files, and castings.

5. The Tippecanoe grit, which is a fairly loose, hard grit, used for grinding wood pulp, springs, files, and heavy forgings.

6. The Marietta grit, which is soft and loose, is used largely in grinding saws, machine knives, and other highly tempered, thin steel tools.

7. The Huron (Michigan) grit is a fine, sharp grit, used for cutlery, mowing machine sections, and tools of that character, where a fine edge is required.

An eighth might be added—the Peninsula grit—a hard and coarse grit, used for grinding wood pulp. In addition to these grades of stone, a grit known as Euclid stone, which contains about 70 per cent of fine silica and 30 per cent of clay, is used for whetters, principally in cutlery works, for polishing out the scratches made by the ordinary grindstone. The production is small, but important.

It may be well to mention here the grades of grindstones that are imported into the United States, as they are used for special purposes for which they seem to be particularly adapted. A grindstone made from a coarse, hard sandstone is imported from Bavaria, and is used particularly for razor grinding. A fine, hard grindstone, called the Craigleith, is imported from Edinburgh, and is used for special purposes in the glass trade.

Although sandstone suitable for the manufacture of grindstones is not uncommon, the variety adapted to the manufacture of a pulpstone is somewhat rare. A considerable demand for pulpstones rose when paper began to be manufactured from wood pulp. In this manufacture a stone is required that can be run in hot water. The Peninsula grit obtained from Peninsula, Tippecanoe, and Empire, Ohio, if carefully selected, ought to make a good pulpstone, which should easily compete with that imported from Newcastle-upon-Tyne, England.

The natural grindstone manufactured from sandstone was formerly in universal use in all kinds of manufacturing plants and in the household, but there has been introduced successfully during the past ten years a grindstone made from emery or corundum. While at the present time only the smaller sized grindstones for household use are made of these materials, it is possible that in the near future large wheels will be made that will rival some of the larger grindstones.

Oilstones, whetstones, and scythestones.—The terms oilstone, whetstone, and scythestone are used somewhat ambiguously, and often the same stone when used for one purpose will be called an oilstone, and when used for another purpose a whetstone, or even a scythestone. The term oilstone has come to be applied to all stones used for sharpening mechanics' tools, for the reason that it is necessary to use oil on most of them to prevent the stone from becoming hot and thus heating the tool, and also to prevent the small particles of steel that are ground off the tools from entering into the pores of the stone.

A considerable change from one census to another is noticeable in the oilstone, whetstone, and scythestone industry in respect to the stone that has the greatest use. While the sale of oilstones and whetstones has increased, or at least held its own, in the United States since 1889, there has been a considerable falling off in the sale of scythestones. This is undoubtedly due to the small number of scythes, sickles, etc., used at the present time, these having been largely replaced by improved agricultural machines and implements. Scythestones are now used in quantity only in those states or countries into which the improved agricultural machines have not yet been introduced. Thus, while the production of scythestones in the United States has remained about the same, it has become necessary to seek a market for them in foreign countries, and a considerable proportion of the production is exported.

The whetstone producing rocks are all sedimentary in origin, and include quartz-mica-schist, sandstone, novaculite, and intermediate rocks. These are found abundantly in various localities, so that there are probably but few countries which have not within their borders a supply of some kind of stone suitable for making whetstones. Although the material for manufacturing whetstones is so common, only those quarries which produce stones of superior quality and have the greatest advantages for manufacturing and shipping can survive the competition in the trade. This is of course the reason the production of whetstones is confined to a few localities. Occasionally a stone is found of exceptional quality, as the novaculite of Arkansas, for which there is a large demand, although the price may be much higher than that of other whetstones. At the present time the domestic supply of whetstones is obtained from Arkansas, Indiana, Ohio, New Hampshire, and Vermont. There is undoubtedly considerable whetstone material utilized in other states, but those mentioned are the only ones that have produced this abrasive for the market.

At the whetstone quarries in Arkansas, which are in Garland and Saline counties, principally at and in the vicinity of Quarry or Whetstone mountain, Garland county, there is obtained the novaculite (sandstone) from which is manufactured the best and most valuable natural oilstone or whetstone on the market. The quality of the rock varies greatly, even in different parts of the same quarry, but two distinct types of stone or grit are recognized, which are known on the market as the Arkansas and Washita. The latter is less dense and much more porous than the Arkansas. Both of these types are divided into two grades, known as soft and hard. They are used principally in the form of small wheels, oilstones of different shapes, and points such as are used by engravers, surgeons, carvers, dentists, jewelers, watchmakers, and diesinkers.

The sandstone of Orange county, Ind., furnishes a whetstone known as the Hindostan or Orange stone, which is quarried in French Lick and Northwest townships. The stone is fine grained and is used for oilstones. It is considered the best low priced sharpening stone for mechanics' tools. A considerable quantity of this stone is now being exported.

At a number of the sandstone quarries in Ohio from which grindstones are obtained, principally at Berea, in Cuyahoga county, and at Grafton, in Lorain county,

a grade of stone is found suitable for whetstones. This stone makes a scythestone that does good work, but it does not stand transportation so well as the scythestone made from schist. At Euclid, Cuyahoga county, is a fine grained sandstone from which a considerable number of oilstones are made. The well-known Deerlick oilstone is made at Chagrin Falls, in the same county, from a fine grained sandstone. Since the introduction of this stone a few years ago its production has increased considerably each year.

In Cortland county, N. Y., near Labrador Lake, a sandstone similar to that quarried in Ohio is found. It is known as Labrador stone, and is used to a limited extent in the manufacture of whetstones, although no product was reported as quarried in 1902.

In Haverhill, Grafton county, N. H., and near Lamoille, Orleans county, Vt., there is a quartz-mica-schist from which are manufactured the celebrated Indian Pond, White Mountain, and Lamoille scythestones. These schists are variable in their structure, so that only portions or bands of them can be utilized. The cutting quality of the stones varies with the compactness of the schists and the percentage of quartz or grit contained. There are two principal grades of stone found at the New Hampshire quarries, which are known as the Indian Pond and the White Mountain. Both of these stones come from the same quarry. The White Mountain is more compact and has a finer texture, and the Indian Pond includes the more laminated varieties of the schist. The name Indian Pond was used as early as 1820 for a stone obtained from a stratum of schist about 7 miles south of Pike Station, near a pond known by the above name. The stones from the quarries at Lamoille are sold under the name of Lamoille stones. At Lisbon, Grafton county, N. H., there occurs a fine grained quartz-mica-schist of a bluish chocolate color, which furnishes a stone known as the chocolate whetstone. It is a medium hard stone and is especially adapted for leather and skinning knives, and it is also used extensively for sharpening cloth cutters' tools, kitchen and carving knives, etc.

Buhrstones and millstones.—The American buhrstone and millstone varies from a sandstone to a quartz conglomerate, which occurs along the eastern slope of the Appalachian mountains, from North Carolina to New York, and is known by different names, according to the locality from which it is obtained. Occasionally a granite is also used in the manufacture of this stone. The states producing buhrstones and millstones in 1902 were New York, North Carolina, Pennsylvania, Vermont, and Virginia, by far the larger production coming from New York. The buhrstone produced in New York is principally from Ulster county, and is known as Esopus stone. The Pennsylvania stones, which are obtained in Lancaster county, are known as Turkey Hill and Cocalico. From Montgomery county, Va., is obtained a buhrstone which is known on the market as Brush mountain stone. In Rowan county, N. C., a granite is quarried and manufactured into millstones, which are sold, for the most part, in North Carolina and Georgia.

Whereas formerly a large number of buhrstones were used in the United States, principally in grinding wheat, now very few are used for that purpose on account of the introduction of the roller mill process. Buhrstones are still used for this purpose only in certain mountain districts where railroad facilities are wanting. New uses, however, have arisen for these stones, and they are now employed quite extensively for grinding the coarser cereals, mineral paint ores, fertilizers, cement rock, barytes, and other minerals. For these purposes the use is increasing each year, although at the census of 1902 the value of the buhrstones produced was only about one-sixth of the value of those reported at the census of 1880. The decided change in this industry began in 1888, and there was a gradual falling off until 1894, when the industry again began to improve with the introduction of the new uses for the stone.

Garnet.—The greater part of the garnet that is mined for abrasive purposes, except the production from North Carolina, is used in the manufacture of garnet paper, which is extensively employed for abrasive purposes in the manufacture of boots and shoes. Nearly all the production from North Carolina is manufactured into wheels, which are sold as emery wheels. The abrasive value of garnet was known to the North American Indians, who engraved shells with tools consisting of garnet points attached to wooden handles.[1]

During 1902 garnet was obtained from Connecticut, New York, North Carolina, and Pennsylvania.

In Connecticut, near Roxbury, Litchfield county, garnet is obtained from a mica-schist, in which it occurs in crystals from less than a quarter of an inch to nearly two inches in diameter. As the rock is crushed, the crystals readily separate from the schist, making a clean garnet concentrate, that is ready for crushing and sizing.

The principal New York garnet localities are near North river, in Warren county, and in Essex county. The mineral occurs in segregated masses, in both gneiss and limestone rocks, varying in size from that of a pigeon's egg to a diameter of 20 feet. Commercially, this garnet is designated (1) as massive garnet, when it is in the larger masses, which are impure; (2) as shell garnet, which is nearly pure garnet; and (3) pocket garnet, when it occurs in small masses or crystals in the gneiss. Of these, the shell garnet is considered the most valuable.

The North Carolina garnet deposits that have been developed are all in Jackson county. The principal mine is on Sugar Loaf mountain, about one and one-half miles from the railroad. The occurrences are all similar, being bands of garnetiferous gneiss in ordinary

[1] United States Geological Survey, Twelfth Annual Report, Part VI, 1889, page 608.

gneiss. These bands are 50 or more feet in width, and average from 15 to 30 per cent of garnet.

In Delaware and Chester counties, Pa., a garnet occurs in small crystals and fragments thickly disseminated through a gneiss which is badly decomposed. A considerable product, reported from Delaware county, is known on the market as rose garnet.

Crystalline quartz.—The production of crystalline quartz that is included under the head of abrasives, is that which is used in the manufacture of sandpaper, scouring soaps, and as a wood finisher. In addition to these uses there are large quantities of quartz sand used in the stonecutting trade, especially by the marble workers. A small amount of quartz is pulverized, and sold under the name of tripoli. Of the production reported for 1902 the larger amount was used as a wood finisher, and was obtained from Connecticut. Most of that used in the manufacture of sandpaper was mined in Pennsylvania.

Infusorial earth and tripoli.—Among the abrasives, infusorial earth and tripoli formed but a small proportion of the production, and of the amount produced less than half was actually used for abrasive purposes. Under the head of infusorial earth and tripoli are included all porous, siliceous earths of organic origin, such as infusorial earth, diatomaceous earth and tripoli, and also a siliceous material which is the residue from an impure siliceous limestone by the leaching out of the calcium carbonate. The material produced in 1902 was from California, Georgia, Maryland, Missouri, New Hampshire, New York, and Virginia.

Pumice.—The production of pumice in the United States has been very erratic during the time for which statistics of this material have been published, although commercial deposits are known to occur in large quantity, especially in Utah and Nebraska. On account, however, of the distance of these deposits from the railroad, and from the large markets, they are not able to compete with the pumice imported from Lipari, Italy, which is shipped largely as ballast, and which, after being ground and bolted, is sold in New York at from 2 to 2½ cents per pound. These Lipari deposits supply almost the entire demand for pumice. During 1902 the entire production of pumice in the United States was from the Nebraska deposits, and was used largely in the manufacture of soaps and scouring powders.

Corundum and emery.—The natural abrasives that have the highest abrasive efficiency are corundum and emery, and there is an increasing demand for these, which is due largely to the increase in manufacturing, especially of agricultural machines, but also to the improved methods that have been devised for making emery and corundum stones and wheels of all shapes and sizes. These abrasives, manufactured into wheels of various sizes, have replaced, to some extent, the smaller grindstones in manufacturing establishments. They have also been manufactured into oilstones and whetstones, and have successfully competed with the natural product, although selling at a higher price. With the exception of certain emery wheels made by the silicate process, and used for saw gummers, no large emery wheels have as yet been made. Even if large vitrified emery wheels could be made, it is a question whether their cost could be lowered sufficiently to permit them to enter into competition with the grindstone, and also whether the emery stone would do as satisfactory work as the grindstone for certain kinds of grinding.

Of the corundum and emery used in the United States about one-half is produced in this country, the remainder being obtained from the Turkish and Grecian emery mines, and from the Canadian corundum mines. There were but a few tons of corundum produced in the United States in 1902, the production of this type of abrasives being almost entirely of the emery variety. Corundum was formerly regarded as occurring sparingly in nature, but it is now known to have a rather wide occurrence and to exist in commercial quantity in many localities. With the known occurrences of this mineral in this country there should be no difficulty in such production of it as to fully satisfy the markets' demand. Competition with the Canadian corundum will be strong, and if there is a decrease in price, the location of the deposits for easy mining and sufficient railroad facilities will need to be very favorable if they are to be profitably worked. The value of corundum in 1902 was from 7 to 10 cents per pound when cleaned and sized. Emeries varied in price from 1 to 5 cents per pound.

The more promising deposits of corundum in the United States are as follows: In North Carolina, at Corundum Hill, Macon county; at Sapphire, Jackson county; and at Brick creek, Clay county. In Georgia, at Laurel creek, Rabun county; and in Montana, on the headwaters of Elk creek, Gallatin county. The emery deposits are near Peekskill, N. Y., and at Chester, Mass., the latter furnishing the most of the emery produced in the United States. During 1902 there was also a small production in Montana.

TABLE 4.—DETAILED SUMMARY, BY STATES: 1902.

	United States.	Arkansas.	Connecticut.	Indiana.	New York.	Ohio.	Pennsylvania.	Virginia.	All other states.[1]
Number of mines or quarries	82	4	6	6	30	8	5	5	18
Number of operators	75	3	5	5	30	8	5	5	14
Character of ownership:									
Individual	39	2	2	4	22	1	4	1	3
Firm	17		2	1	4	3		3	4
Incorporated company	19	1	1		4	4	1	1	7
Salaried officials, clerks, etc.:									
Total number	75	2	9		17	25	1	3	18
Total salaries	$48,008	$1,050	$6,318		$12,139	$13,192	$840	$1,942	$12,527
General officers—									
Number	16		2		5	5		2	2
Salaries	$13,101		$2,000		$3,300	$2,880		$1,471	$3,450
Superintendents, managers, foremen, surveyors, etc.—									
Number	43	2	5		10	15	1	1	9
Salaries	$25,506	$1,050	$3,118		$7,339	$7,882	$840	$471	$4,806
Foremen below ground—									
Number	1								1
Salaries	$600								$600
Clerks—									
Number	15		2		2	5			6
Salaries	$8,801		$1,200		$1,500	$2,430			$3,671
Wage-earners:									
Aggregate average number	610	23	19	24	155	149	19	20	201
Aggregate wages	$296,914	$10,615	$9,521	$9,063	$81,710	$69,336	$8,226	$8,273	$100,170
Above ground—									
Total average number	585	23	19	24	154	149	19	18	179
Total wages	$280,416	$10,615	$9,521	$9,063	$81,060	$69,336	$8,226	$7,025	$85,570
Engineers, firemen, and other mechanics—									
Average number	75	1	1		9	27	2		35
Wages	$13,772	$600	$600		$5,124	$15,313	$840		$21,295
Miners or quarrymen, and stonecutters—									
Average number	387	22	18	23	191	88	15	18	99
Wages	$176,798	$10,015	$8,921	$8,688	$52,623	$40,305	$6,786	$7,025	$42,435
Boys under 16 years—									
Average number	3			1		2			
Wages	$912			$375		$537			
All other wage-earners—									
Average number	120				41	32	2		45
Wages	$58,934				$23,313	$13,181	$600		$21,840
Below ground—									
Total average number	25				1			2	22
Total wages	$16,498				$650			$1,248	$14,600
Miners—									
Average number	15				1			2	12
Wages	$10,648				$650			$1,248	$8,750
Miners' helpers—									
Average number	10								10
Wages	$5,850								$5,850
Average number of wage-earners at specified daily rates of pay:									
Engineers—									
$1.25 to $1.49	1								1
$1.50 to $1.74	9	1			1	3	2		2
$1.75 to $1.99	1				1				
$2.00 to $2.24	22		1			9			12
$2.25 to $2.49	3				1	1			1
$2.50 to $2.74	2								2
$3.00 to $3.24	1					1			
$3.50 to $3.74	1								1
Firemen—									
$1.00 to $1.24	1								1
$1.75 to $1.99	14					3			11
Machinists, blacksmiths, carpenters, and other mechanics—									
$0.75 to $0.99	1								1
$1.50 to $1.74	3				2	1			
$1.75 to $1.99	7				1	6			
$2.00 to $2.24	7				3	3			1
$2.25 to $2.49	1								1
$4.00 to $4.24	1								1
Miners or quarrymen, and stonecutters—									
$0.75 to $0.99	13								13
$1.00 to $1.24	38			10	1	7		4	16
$1.25 to $1.49	66			3	3	31		11	15
$1.50 to $1.74	160	22	12	10	43	32	14	3	24
$1.75 to $1.99	70		5		33	3			29
$2.00 to $2.24	35		1		24	3	1	2	4
$2.25 to $2.49	4					3			1
$2.50 to $2.74	7					6			1
$2.75 to $2.99	1				1				
$3.00 to $3.24	8								8
Miners' helpers—									
$1.50 to $1.74	5								5
$1.75 to $1.99	5								5
Boys under 16 years—									
$0.75 to $0.99	2					2			
$1.25 to $1.49	1			1					
All other wage-earners—									
$0.75 to $0.99	6								6
$1.00 to $1.24	14					2	2		10
$1.25 to $1.49	16				1	13			2
$1.50 to $1.74	35					17			18
$1.75 to $1.99	21				20				1
$2.00 to $2.24	20				20				
$2.50 to $2.74	6								6
$3.00 to $3.24	2								2

[1] Includes operators distributed as follows: California, 1; Georgia (operator included under talc and soapstone); Kentucky, 1; Maryland, 1; Massachusetts, 2; Michigan (operator included under sandstones and quartzites); Missouri, 2; Montana, 1; Nebraska, 1 (2 quarries); New Hampshire, 1 (3 quarries); North Carolina, 1; Vermont, 1 (2 quarries); West Virginia, 2; and Wyoming (operator included under sandstones and quartzites).

TABLE 4.—DETAILED SUMMARY, BY STATES: 1902—Continued.

	United States.	Arkansas.	Connecticut.	Indiana.	New York.	Ohio.	Pennsylvania.	Virginia.	All other states.
Average number of wage-earners employed during each month:									
Men 16 years and over—									
January	427	16	6	18	94	126	9	20	138
February	437	16	6	21	97	119	9	20	149
March	475	26	8	20	106	132	9	21	153
April	605	26	21	20	166	136	22	23	191
May	669	27	22	29	172	138	22	28	231
June	673	27	17	29	165	152	22	22	239
July	675	27	17	30	166	155	22	19	239
August	700	27	33	29	163	171	22	19	236
September	696	26	29	20	192	169	22	18	220
October	696	26	23	20	188	169	23	18	220
November	639	16	23	20	183	154	23	16	204
December	592	16	23	20	168	143	23	16	183
Boys under 16 years—									
January	2	.....	.....	.....	.....	2	.....	.....	.....
February	3	.....	.....	1	.....	2	.....	.....	.....
March	3	.....	.....	1	.....	2	.....	.....	.....
April	3	.....	.....	1	.....	2	.....	.....	.....
May	3	.....	.....	1	.....	2	.....	.....	.....
June	3	.....	.....	1	.....	2	.....	.....	.....
July	3	.....	.....	1	.....	2	.....	.....	.....
August	3	.....	.....	1	.....	2	.....	.....	.....
September	3	.....	.....	1	.....	2	.....	.....	.....
October	3	.....	.....	1	.....	2	.....	.....	.....
November	3	.....	.....	1	.....	2	.....	.....	.....
December	4	.....	.....	2	.....	2	.....	.....	.....
Miscellaneous expenses:									
Total	$12,410	$685	$2,577	$300	$6,720	$13,275	$696	$1,085	$17,072
Royalties and rent of mine and mining plant	$8,421	$175	$2,091	.....	$1,714	$2,198	$588	$1,050	$605
Rent of offices, taxes, insurance, interest, and other sundries	$33,989	$510	$486	$300	$5,006	$11,077	$108	$35	$16,467
Cost of supplies and materials	$80,309	$1,625	$1,617	$1,455	$12,264	$23,384	$926	$205	$38,833
Value of product	$1,177,711	$21,275	$42,895	$16,950	$189,345	[1] $587,284	$20,738	$16,335	[2] $282,889
Power:									
Total horsepower	2,495	21	80	31	275	647	35	200	1,206
Owned—									
Engines—									
Steam—									
Number	71	2	2	4	3	23	1	2	34
Horsepower	2,300	21	80	27	265	635	35	200	1,037
Gas or gasoline—									
Number	7	.....	.....	1	.....	.....	.....	.....	6
Horsepower	88	.....	.....	4	.....	.....	.....	.....	84
Other power—									
Number	3	.....	.....	.....	1	.....	.....	.....	2
Horsepower	95	.....	.....	.....	10	.....	.....	.....	85
Rented—									
Other than electric—									
Horsepower	12	.....	.....	.....	.....	12	.....	.....	.....
Electric motors owned—									
Number	1	.....	.....	.....	.....	.....	.....	.....	1
Horsepower	5	.....	.....	.....	.....	.....	.....	.....	5

[1] Includes product valued at $408,598 obtained in quarries producing other than abrasive materials.
[2] Includes product valued at $35,941 obtained in quarries producing other than abrasive materials.

TABLE 5.—DETAILED SUMMARY, BY CLASSES: 1902.

	All abrasives.	Buhrstones and millstones.	Corundum and emery.	Crystalline quartz.	Garnet.	Grindstones and pulpstones.	Infusorial earth, tripoli, and pumice.	Oilstones, whetstones, and scythestones.
Number of mines or quarries	82	29	5	6	7	9	11	15
Number of operators	75	29	5	5	7	9	10	10
Character of ownership:								
Individual	39	23	1	3	1	1	3	7
Firm	17	6			3	3	4	1
Incorporated company	19		4	2	3	5	3	2
Salaried officials, clerks, etc.:								
Total number	75	7	9	8	12	25	8	6
Total salaries	$48,008	$4,682	$5,960	$6,030	$9,178	$13,042	$4,016	$5,100
General officers—								
Number	16	1	4	2	2	2	1	4
Salaries	$13,101	$471	$2,950	$2,000	$2,160	$480	$1,000	$4,050
Superintendents, managers, foremen, surveyors, etc.—								
Number	43	6	2	4	6	18	5	2
Salaries	$25,506	$4,211	$1,199	$2,830	$4,028	$10,132	$2,056	$1,050
Foremen below ground—								
Number	1		1					
Salaries	$600		$600					
Clerks—								
Number	15		2	2	4	5	2	
Salaries	$8,801		$1,211	$1,200	$3,000	$2,430	$960	
Wage-earners:								
Aggregate average number	610	86	47	29	118	210	35	85
Aggregate wages	$296,914	$39,562	$32,871	$13,592	$59,632	$99,598	$13,682	$37,977
Above ground—								
Total average number	585	86	25	29	118	210	32	85
Total wages	$280,416	$39,562	$18,271	$13,592	$59,632	$99,598	$11,784	$37,977
Engineers, firemen, and other mechanics—								
Average number	75	4	6	1	10	48	2	4
Wages	$43,772	$2,264	$5,525	$600	$4,914	$27,110	$930	$2,429
Miners or quarrymen, and stonecutters—								
Average number	387	80	11	26	61	118	20	71
Wages	$176,798	$36,734	$5,546	$12,392	$29,505	$54,270	$7,254	$31,097
Boys under 16 years—								
Average number	8					2		1
Wages	$912					$537		$375
All other wage-earners—								
Average number	120	2	8	2	47	42	10	9
Wages	$58,934	$564	$7,200	$600	$25,213	$17,681	$3,600	$4,076
Below ground—								
Total average number	25		22				3	
Total wages	$16,498		$14,600				$1,898	
Miners—								
Average number	15		12				3	
Wages	$10,648		$8,750				$1,898	
Miners' helpers—								
Average number	10		10					
Wages	$5,850		$5,850					
Average number of wage-earners at specified daily rates of pay:								
Engineers—								
$1.25 to $1.49	1				1			
$1.50 to $1.74	9	1			2	3	2	1
$1.75 to $1.99	1				1			
$2.00 to $2.24	22			1		20		1
$2.25 to $2.49	3		2					1
$2.50 to $2.74	2	1	1					
$3.00 to $3.24	1					1		
$3.50 to $3.74	1		1					
Firemen—								
$1.00 to $1.24	1				1			
$1.75 to $1.99	14					14		
Machinists, blacksmiths, carpenters, and other mechanics—								
$0.75 to $0.99	1				1			
$1.50 to $1.74	3	1			1	1		
$1.75 to $1.99	7				1	6		
$2.00 to $2.24	7	1			2	3		1
$2.25 to $2.49	1		1					
$4.00 to $4.24	1		1					
Miners or quarrymen, and stonecutters—								
$0.75 to $0.99	13				12			1
$1.00 to $1.24	38	4				9	14	11
$1.25 to $1.49	66	14			1	43	4	4
$1.50 to $1.74	160	40	8	21	10	32	1	48
$1.75 to $1.99	70	16	8	4	18	24		
$2.00 to $2.24	35	5		1	20	1	3	5
$2.25 to $2.49	4					3		1
$2.50 to $2.74	7					6		1
$2.75 to $2.99	1	1						
$3.00 to $3.24	8		7				1	
Miners' helpers—								
$1.50 to $1.74	5		5					
$1.75 to $1.99	5		5					
Boys under 16 years—								
$0.75 to $0.99	2					2		
$1.25 to $1.49	1							1
All other wage-earners—								
$0.75 to $0.99	6				6			
$1.00 to $1.24	14			2		2	10	
$1.25 to $1.49	16	2			1	13		
$1.50 to $1.74	35					27		8
$1.75 to $1.99	21				20			1
$2.00 to $2.24	20				20			
$2.50 to $2.74	6		6					
$3.00 to $3.24	2		2					

TABLE 5.—DETAILED SUMMARY, BY CLASSES: 1902—Continued.

	All abrasives.	Buhrstones and millstones.	Corundum and emery.	Crystalline quartz.	Garnet.	Grindstones and pulpstones.	Infusorial earth, tripoli, and pumice.	Oilstones, whetstones, and scythestones.
Average number of wage-earners employed during each month:								
Men 16 years and over—								
January	427	74	36	17	62	149	29	60
February	437	76	37	17	62	153	29	63
March	475	87	35	17	68	165	29	74
April	605	92	38	27	137	193	31	87
May	669	98	47	28	143	212	38	103
June	673	87	56	28	135	231	38	98
July	675	85	59	28	135	228	36	104
August	700	83	51	44	135	249	36	102
September	696	85	59	40	145	243	37	87
October	696	91	55	34	138	248	39	91
November	639	95	42	34	140	218	39	71
December	592	79	49	34	116	207	39	68
Boys under 16 years—								
January	2	.....	.....	.....	.....	2	.....	.....
February	3	.....	.....	.....	.....	2	.....	1
March	3	.....	.....	.....	.....	2	.....	1
April	3	.....	.....	.....	.....	2	.....	1
May	3	.....	.....	.....	.....	2	.....	1
June	3	.....	.....	.....	.....	2	.....	1
July	3	.....	.....	.....	.....	2	.....	1
August	3	.....	.....	.....	.....	2	.....	1
September	3	.....	.....	.....	.....	2	.....	1
October	3	.....	.....	.....	.....	2	.....	1
November	3	.....	.....	.....	.....	2	.....	1
December	4	.....	.....	.....	.....	2	.....	2
Miscellaneous expenses:								
Total	$42,410	$1,480	$2,779	$1,950	$4,952	$24,433	$2,263	$4,553
Royalties and rent of mine and mining plant	$8,421	$636	$1,091	$1,825	$1,341	$2,003	$1,050	$475
Rent of offices, taxes, insurance, interest, and other sundries	$33,989	$844	$1,688	$125	$3,611	$22,430	$1,213	$4,078
Cost of supplies and materials	$80,309	$1,809	$26,114	$950	$10,128	$31,349	$2,297	$7,662
Value of product	$1,177,711	[1] $59,808	$104,605	$43,085	$132,820	[2] $667,431	[3] $55,994	[4] $113,968
Power:								
Total horsepower	2,495	85	110	20	430	1,247	410	193
Owned—								
Engines—								
Steam—								
Number	71	.....	2	1	7	41	7	13
Horsepower	2,300	.....	30	20	420	1,235	410	185
Gas or gasoline—								
Number	7	.....	3	.....	.....	.....	.....	4
Horsepower	88	.....	80	.....	.....	.....	.....	8
Other power—								
Number	3	2	.....	.....	1	.....	.....	.....
Horsepower	95	85	.....	.....	10	.....	.....	.....
Rented—								
Other than electric—								
Horsepower	12	.....	.....	.....	.....	12	.....	.....
Electric motors owned—								
Number	1	.....	.....	.....	.....	.....	1	.....
Horsepower	5	.....	.....	.....	.....	.....	5	.....

[1] Includes $1,425 quarried with granite.
[2] Includes $403,066 quarried with sandstone.
[3] Includes $1,436 mined with talc and soapstone.
[4] Includes $38,612 quarried with sandstone.

BORAX

BORAX.

By Joseph Struthers, Ph. D.

The first commercial production of borax in the United States was in 1864, when 12 short tons were mined in California. Since that year the production has fluctuated from nothing in 1869, 1870, and 1871, to 19,142 short tons in 1902. Up to the present investigation borax has never been separately treated in the census of mines and mining. Table 1 is a summary of the statistics for 1902.

Table 1.—*Summary: 1902.*

Number of mines or quarries	6
Number of operators	6
Salaried officials, clerks, etc.:	
Number	14
Salaries	$18,128
Wage-earners:	
Average number	153
Wages	$114,865
Miscellaneous expenses	$47,606
Cost of supplies and materials	$213,538
Product:[1]	
Quantity, short tons	19,142
Value	$2,383,614

[1] The United States Geological Survey reports 20,004 short tons, valued at $2,538,614, which includes 862 short tons of boric acid, valued at $155,000. This acid, representing a manufacture, is not reported by the Census.

There were only 6 productive mines or quarries in 1902, and these were not widely separated geographically. Four were in California, and 1 each in Nevada and Oregon. Each company operated a single mine only. An average of about 25 wage-earners for each mine is shown. For the industry as a whole a total average for the year of only 167 salaried employees and wage-earners is reported. Compared with the amount paid in wages and salaries and for miscellaneous expenses, the cost of supplies and materials appears large.

Six mines were idle in 1902—3 in California, 2 in Nevada, and 1 in Oregon—and at 1 mine in California development work was carried on.

Capital stock of incorporated companies.—Every active company reported was organized as a corporation. Their capitalization appears in Table 2.

Table 2.—*Capitalization of incorporated companies: 1902.*

Number of incorporated companies	6
Capital stock:	
Total authorized—	
Number of shares	823,750
Par value	$3,175,000
Total issued—	
Number of shares	822,250
Par value	$3,025,000
Dividends paid	$231,600
Common—	
Authorized—	
Number of shares	573,750
Par value	$2,925,000
Issued—	
Number of shares	572,250
Par value	$2,775,000
Dividends paid	$231,600
Preferred—	
Authorized—	
Number of shares	250,000
Par value	$250,000
Issued—	
Number of shares	250,000
Par value	$250,000

These companies, as a rule, refine the crude borax, and it must be remembered that the capitalization shown includes that utilized for the equipment and maintenance of the refining plants. Refining, however, is too closely related to mining to allow of satisfactory segregation.

The par value of the total amount of capital stock authorized for these companies was $3,175,000, representing 823,750 shares of both common and preferred stock. Shares to the number of 822,250, with a par value of $3,025,000, were issued. Of these 572,250 shares were of common stock with a par value of $2,775,000, and 250,000 shares were of preferred stock with a par value of $250,000. All the preferred stock authorized was issued, as was all but 1,500 shares of the common stock. There was paid $231,600 in dividends on the common stock issued. This is equivalent to 8.35 per cent on its par value. No dividend was paid upon the preferred stock. There was no bonded indebtedness.

Employees and wages.—The average number of wage-earners employed during each month of 1902, and the

daily rates of pay, are shown in Table 6. The importance of this industry is not to be judged by the number of men to whom it gave employment, only 174 at the maximum, during the cool months of the year. In summer, from June until September, the heat in the southeastern counties of California does not permit active operations, which as a consequence are reduced to a minimum. On the coming of cooler weather, however, operations are at once resumed, as appears from the number of men reported employed in September and October.

Here relatively high rates of pay are shown. Fifty per cent of the engineers received from $3.25 to $3.49 per diem; 3 of the 6 mechanics got above $3.50 per diem. Over 71 per cent of those classed as miners or quarrymen received from $2.50 to $3.24 per diem. All of the miners' helpers received from $2.50 to $2.74. Of "all other wage-earners" none was paid less than $1.50 per diem, and more than two-thirds, or 67.4 per cent, received from $2 to $3.24.

Mechanical power.—Mechanical power to the amount of 338 horsepower was reported. Two hundred and five horsepower were furnished by 5 steam engines, 123 horsepower by 11 gas or gasoline engines, and 10 horsepower by 1 water wheel. There was also 1 electric motor of 1 horsepower.

Production.—Table 3 shows the annual production of borax in California from 1889 to 1902, as reported by the United States Geological Survey.

TABLE 3.—*Production of borax in California: 1889 to 1902.*

[United States Geological Survey, "Mineral Resources of the United States," 1902.]

YEAR.	Quantity (short tons).	Value.
1889	965	$145,473
1890	3,201	480,152
1891	4,267	640,000
1892	5,525	838,787
1893	3,955	593,292
1894	5,770	807,807
1895	5,959	595,900
1896	6,754	675,400
1897	8,000	1,080,000
1898	8,300	1,153,000
1899	20,357	1,139,882
1900	25,837	1,013,251
1901	23,231	1,012,118
1902[1]	20,004	2,538,614

[1] Includes small quantities and value of same, mined in Oregon and Nevada. To separate would reveal the operations of single operators.

Since 1864, when the first production was reported, 156,354 short tons of borax have been produced in California. This is practically the production for the whole United States. Prior to 1890 the number of short tons produced annually had passed the thousand mark only in 1875, 1876, 1884, 1886, 1887, and 1888. In 1889 the production sank slightly below this mark, only to rise with a bound in 1890 to 3,201 tons, the greatest up to that time. From then until 1900, with the exception of 1893 when there was a temporary setback, it gradually increased to 25,837 tons. In 1901 a production of 23,231 tons was reported, and in 1902, 19,142 tons, exclusive of the 862 tons of boric acid reported by the Geological Survey. The decrease in output for these years is apparent only, for it must be borne in mind that the figures of production are for both crude and refined, and that the proportions of each may vary greatly each year. The tendency of late years has been to do as much refining or concentrating as is possible at the place of production. Thus in 1902, while 43,010 short tons of crude ore were mined, 40,410 tons of this received some treatment at the mines, making 16,542 tons of refined product, which, with the remaining 2,600 tons of crude, comprise the 19,142 tons reported.

Table 4 gives the production of borax and boron compounds in the principal producing countries of the world from 1896 to 1901, inclusive, as reported by the United States Geological Survey.

TABLE 4.—*The production of borax, borates, etc., in the principal countries of the world: 1896 to 1901.*[1]

[United States Geological Survey, "Mineral Resources of the United States," 1902.]

[Metric tons.]

YEAR.	United States (calcium borate).	Chile (calcium borate).[2]	India (borax).[2]	Germany (boracite).	Italy (boric acid, crude).	Peru (calcium borate).[2]	Turkey (pandermite).[2,3]
1896	12,310	7,486	340	184	2,616	1,179	12,626
1897	17,600	3,168	280	198	2,704	11,850	11,375
1898	13,911	7,034	184	230	2,650	7,178	(4)
1899	21,834	14,951	250	183	2,674	7,638	(4)
1900	23,456	13,177	224	232	2,491	7,080	(4)
1901	16,227	11,547	162	184	2,558	(5)	(4)

[1] From official reports of the respective countries, except the United States.
[2] Exports.
[3] Fiscal years.
[4] Total exports, 1897 to 1901, amounted to 43,851 tons, valued at £789,318.
[5] Statistics not yet available.

The control of the borax industry in the world is now practically in the hands of the Borax Consolidated (Limited), an international trade combination which was formed in 1898 with a capital stock of £1,400,000 to acquire all the important borax-producing properties in the world. This concern owns or controls borax lands and refineries in the United States, England, France, Chile, Peru, and Turkey.

The future of the borax industry indicates an increased demand for borax and boric acid, as well as an increase in the number of industrial purposes to which these and their compounds are applicable. At the present time the various industries in which boron compounds are used include the manufacture of earthen, china, and glass ware, enameled ironware, smelting, tanning, calico printing, cement making, color manufacture, bleaching, soapmaking, and meat packing. Boron compounds are also used in laundries and for many household, toilet, and surgical purposes.

There has been considerable discussion as to the use of boric acid as a preservative for food, and the preponderance of the evidence seems to be in favor of its employment in small quantities as an entirely harmless preservative, but only a small proportion of the total supply in the world is utilized for this purpose.

In order to provide data from which may be calculated an estimate of the consumption of borax and boron salts in the United States, Table 5, showing the imports, has been prepared by the United States Geological Survey from the reports of the United States Treasury Department.

TABLE 5.—*Imports of borax and borates into the United States: 1889 to 1902.*

[United States Geological Survey, "Mineral Resources of the United States," 1902.]

YEAR.	BORAX.		BORATES, CALCIUM, AND SODIUM (CRUDE AND REFINED SODIUM BORATE).		BORIC ACID.	
	Quantity (pounds).	Value.	Quantity (pounds).	Value.	Quantity (pounds).	Value.
1889	.....	.....	Nil.	Nil.	676,786	$36,814
1890	.....	.....	29,608	$800	867,802	43,967
1891	.....	.....	414,151	17,681	666,765	41,019
1892	.....	.....	40	6	701,625	39,418
1893	11,230	$1,327	543,967	13,659	771,775	40,568
1894	1,812	225	441,066	11,427	298,990	19,282
1895	612,730	26,429	4,234,261	105,604	925,158	42,056
1896	11,376	796	4,307,100	104,951	555,769	21,899
1897	19,087	1,128	5,204,612	79,268	.....	.....
1898	10,232	962	4,235,856	92,108	.....	.....
1899	51,221	3,508	42,165	2,979	582,002	20,560
1900	273,706	9,937	58,294	4,306	473,251	17,436
1901	545,045	20,643	103,700	9,411	725,005	26,629
1902	684,537	20,795	186,807	12,002	822,907	30,439

A detailed summary showing the statistics for borax during 1902 is given in Table 6.

DESCRIPTIVE.

Historical.—The occurrence of borax in the United States was discovered in California by Dr. John A. Veatch, January 8, 1856. Having boiled a small quantity of water from Lick Spring (then known as Tuscan Spring), Doctor Veatch noticed that, as the water cooled, crystals formed and adhered to the sides of the vessel. These crystals proved later to be sodium biborate, or borax. Shortly afterwards Doctor Veatch found small quantities of borax at the mouth of the Pitt river, in Shasta county, and traces of this salt in numerous springs in the Coast Range mountains; but it was not until September, 1856, that he discovered the extensive marsh deposits on the eastern side of Clear Lake, in Lake county, which subsequently furnished a large share of the borax produced in the United States.

The year 1864 witnessed the beginning of the borax industry in this country. In that year 12 short tons (24,304 pounds) of borax were obtained by evaporating the saline waters from Borax Lake, adjacent to and connected with Clear Lake, in Lake county, 80 miles north of San Francisco. Later the waters of the lake were enriched by the addition of crystalline borax collected from the alkaline marshes surrounding the lake.

Until the early seventies, the output of borax in California was obtained solely from the waters of Clear Lake and other lakes in the state, but after that time the discovery of large quantities of pure borax in many of the alkaline marshes in eastern California and western Nevada, caused the abandonment of the lake refineries and the erection of new plants, notably near Columbus, Nev.; at Searles marsh in the Amargosa valley; and at the mouth of Furnace creek in Death Valley, California. Despite the difficulty and great cost of transporting the refined product by teams 100 miles to the railroad, the refineries continued in successful operation for several years, until the relatively large increase in the domestic output, together with the increased imports from Italy, so reduced the price that the working of the marsh deposits became no longer profitable and the refineries were closed down. About the year 1890 it was found that the borax crust on many of the marshes had been formed by the leachings of beds of calcium borate (borate of lime) in the Tertiary lake sediments in that region. Owing to the large extent of these bedded deposits, which possessed also the double advantage of containing a purer grade of mineral and of being more easily accessible than the marsh deposits, the borax industry as it existed at that time was revolutionized. A mine was started on a bedded deposit of from 6 to 10 feet in thickness at Borate, 12 miles northeast of Daggett, Cal., in San Bernardino county, and a refining plant was erected by the Pacific Coast Borax Company. This company was organized in 1888, and at the present time is the chief producer of borax in the United States, as well as the producer of a large part of the output of boric acid. The ore at Borate consists of colemanite (a calcium borate mineral) in large masses more or less connected by stringers and bands in a bedded deposit of from 5 to 30 feet in thickness, interstratified in lake sediments. The great value of this deposit led to extensive prospecting in other parts of the state, which has resulted in the discovery in Death Valley of enormous quantities of colemanite reported to exceed greatly in value the deposit at Borate. Both at Borate and in Death Valley the deposits are of similar occurrence, being contained in a regular stratum interbedded with semi-indurated sands and clays which comprise the bulk of the strata. These beds are regarded as of Tertiary age, and are supposed to have been deposited from inclosed bodies of water. Large plants for the concentration and refining of the crude ore have been erected in California: At Alameda, near San Francisco (inoperative during 1902), at Marion, and at Daggett. The largest borax refinery in the United States, however, is at Bayonne, New Jersey.

Review of the borax industry during 1902.—There were 4 companies engaged in the borax industry in California during 1902—the Pacific Coast Borax Company, the American Borax Company, the Western Borax Works, and the Frazier Borate Mining Company. The Pacific Coast Borax Company, continued to supply a sufficient quantity of borax to satisfy the requirements

of the market; and apart from its operations at Borate, prospecting work for other colemanite deposits has been carried on in Death Valley and much additional property has been acquired. The deposits in Amargosa Valley were carefully examined and large sample lots of ore were transported by traction engines to Manville, 100 miles distant, and thence by rail to the refinery for testing the quality, in order to determine the value of the property. The large borax refinery at Bayonne, N. J., was destroyed by fire in April, 1902, but has since been entirely rebuilt.

The American Borax Company, is under the control of the Standard Sanitary Company, of Pittsburg, Pa. The plant of this concern at Daggett has been greatly extended by the addition of two 20,000-gallon tanks or digesters for the treatment of the crude material from the adjacent mud deposits by the sulphuric acid process, which is referred to in detail later in this report. The enlargement of this plant has greatly increased the output of boric acid concentrates, and the results have been so satisfactory that a further extension of the plant at Daggett is contemplated. A new refinery is in course of erection at Pittsburg, to which will be shipped the concentrates from Daggett for the final refining.

The mines of the Western Borax Works are located in Inyo county, and those of the Frazier Borate Mining Company in San Bernardino county.

Apart from the output of the above-named concerns, a small quantity of borax has been obtained from the marsh deposits in California and Nevada, but the total amount produced from these scattered sources has been of so little comparative importance that the borax market was in no way affected. During the past few years Oregon has contributed to the domestic supply a small quantity of borax from the marsh deposits in Harney county. The output has averaged about 400 tons annually except in 1902, when 120 tons were reported, as the mining operations had given way greatly to development work. The chief borax producer in this state is the Rose Valley Borax Company, controlling 2,000 acres of rich marsh land near Lake Alvord in the southeastern part of Harney county. The total area of the deposit, which is south of the lake, aggregates approximately 10,000 acres. The ground is level and treeless, and is incrusted with a layer several inches thick containing in addition to sodium borate numerous other salts of sodium. During the long summer months the loose surface deposit is shoveled into small heaps, and is subsequently replaced with a second incrustation within a comparatively short period of time. The stock of crude material collected during the summer is sufficient to enable the refinery to continue in operation throughout the entire year. The crude mineral, containing from 5 to 20 per cent of boric acid in combination with a sodium base, is shoveled into tanks containing boiling water to which is added a proper quantity of chlorine gas or sulphuric acid to decompose the alkali salts and thus liberate the boric acid. After a treatment of twenty-four hours in the tank the clear supernatant liquor is withdrawn to the crystallizing vats and allowed to cool, which causes the boric acid to separate in the form of crystals, leaving a mother liquor, which is used repeatedly until it contains sufficient sodium salts to warrant a separate treatment.

Occurrence.—The principal minerals containing boron are as follows: Sassolite, boric acid (H_3BO_3); borax (tincal), sodium biborate ($Na_2B_4O_7.10H_2O$); ulexite (boronatrocalcite) ($CaNaB_6O_9.8H_2O$); colemanite (impure varieties, priceite and pandermite), calcium borate ($Ca_2B_6O_{11}.5H_2O$); and boracite (stassfurtite), magnesium borate ($2Mg_3B_8O_{15}.MgCl_2$). Boron is also a constituent of several common silicate minerals, notably tourmaline and datolite. Borax, sodium biborate ($Na_2B_4O_7.10H_2O$), is the only important salt derived from boric acid. It occurs native in California, Ceylon, and Thibet, and from the last-named place it is obtained in the form of tincal, an impure crystallized borax containing calcium and magnesium sulphates and chlorides and a greasy substance which is added presumably to protect the crystals from efflorescence and breakage. The tincal is purified by dissolving in warm water and adding limewater and calcium chloride in order to precipitate the grease as a lime soap. After filtering, the pure crystals of boric acid are obtained by evaporating the solution.

Physical and chemical characteristics.—Several forms of borax are used in industrial, medicinal, and laboratory processes—the principal one being prismatic sodium borate (borax, $Na_2B_4O_7.10H_2O$). There is a second variety called "octahedral borax" which contains five molecules of water of crystallization ($Na_2B_4O_7.5H_2O$), forming octahedral crystals. The latter variety, unlike prismatic borax, becomes opaque upon exposure to moist air and is converted by the absorption of water into the prismatic form.

A property of molten borax of great utility in analytical research is that of dissolving various metallic oxides, thereby forming transparent glasses of characteristic colors. By making a borax bead on a loop of platinum wire held in a blowpipe flame, and dissolving therein the substance under examination, the presence of certain metals is easily distinguished.

Borax is also of great value in assaying gold and silver ores, being used to dissolve and remove the base metals from the metallic lead button containing the gold and silver of the sample of ore tested. This property of dissolving oxides is utilized also in soldering and brazing metals that are oxidizable by heat; the molten borax absorbing any oxides formed whose presence mechanically would prevent the close adhesion of the metals so necessary for a proper weld or soldered joint.

Among other important uses are as a constituent of strass or paste for making glass and enamels; as a glaze

for fine earthenware; in combination with shellac as a varnish for stiffening felt hats; with casein as a substitute for gum arabic, and (on account of its antiseptic qualities) as a household soap; as an ingredient of various cosmetics; and as a solution for cleansing the hair.

Boric acid (H_3BO_3) (old name boracic acid): In Tuscany the vapors escaping from the hot springs and from openings in the ground (fumaroles) contain boric acid, and in some places this substance is obtained as crystals by the evaporation of water from these fumaroles. The crystals or crusts produced naturally form the mineral sassolite. The crystals of boric acid are white in color, laminated in structure, and possess a mother-of-pearl luster. They dissolve readily in hot water though very slightly in cold. Upon being heated to 160° C. they lose one-half the water of crystallization and become transformed to pyroboric acid ($H_2B_4O_7$). At a red heat all of the water is expelled and boric anhydride (B_2O_3) results, which, even at high temperatures is stable and nonvolatile, and for this reason it is able to decompose nearly all of the metallic sulphates, forming when fused with them, metallic borates.

Fused boric anhydride when cold resembles ordinary glass in transparency, hardness, and brittleness. The chief uses of boric acid are in the manufacture of borax; in making colored glazes for the decoration of iron, steel, and other metallic objects; in enamels and glazes for pottery; in the manufacture of flint glass and strass or paste from which artificial stones are cut; in making Guignet's green; as an antiseptic in medicine and surgery; and as a preservative for fish, meat, milk, and other foods.

The principal methods used in the manufacture of boric acid are thus described:

The chlorine or Moore process.—In this process, which is used to some extent in England, the crude colemanite in powdered form is suspended in water and heated to 70° C.; then chlorine gas is passed into the liquor and reacts on the colemanite, forming boric acid, calcium chloride, and calcium chlorate. The greater part of the boric acid crystallizes out upon cooling and is subsequently purified by repeated crystallizations. The residue solution, called mother liquor, is used many times until the accumulated calcium salts begin to separate out in the form of crystals.

The hydrochloric acid process.—The mode of procedure in this process is as follows: Two parts by weight of hydrochloric acid and four parts of water (the volume of the latter being kept constant) are used, in which the calcium borate is boiled until dissolved. The boric acid is then crystallized out of the cooled liquor, leaving the calcium chloride still in solution. Before the crystals are in proper condition for packing and shipping, an additional treatment is necessary, which consists of draining, "whizzing," and washing with cold water, concluding with a second and final "whizzing." In Germany the hydrochloric acid process is used to extract the boric acid from the boracite contained in the famous Stassfurt salt deposits. The material is crushed and treated with hydrochloric acid, the resultant pasty mass is dissolved in boiling water and the solid material separated and removed by filtration or decantation; the clear solution is then crystallized in iron tanks, yielding pure crystals of boric acid. The chemical reaction involved is $(2Mg_3B_8O_{15}), MgCl_2 + 12HCl + 18H_2O = 7MgCl_2 + 16H_3BO_3$.

The sulphuric acid process.—In this process calcium borate is treated with sulphuric acid, the reaction yielding soluble boric acid and precipitated calcium sulphate. The boric acid is obtained by leaching with hot water, the solution so produced being concentrated by evaporation until the crystals of boric acid separate out from the solution. In California the process is slightly modified. The borate mud is boiled in huge tanks with water containing sulphurous acid, which decomposes the calcium borate, thereby liberating the boric acid in the solution and leaving the calcium in the form of insoluble calcium sulphate. As before, the boric acid is dissolved by leaching with hot water, which, however, extracts also a small quantity of other soluble salts. For this reason fractional crystallization is necessary in order to obtain a fairly pure product. In a few works the insoluble calcium sulphate is separated and removed by passing the muddy solution from the tanks through filter presses.

The sulphuric acid process is sometimes used to decompose the boracite of the Stassfurt deposits, and in this case Epsom salt is obtained as a by-product from the magnesium sulphate contained in the mother liquor, according to the following chemical reaction: $(2Mg_3B_8O_{15}), MgCl_2 + 7H_2SO_4 + 18H_2O = 7MgSO_4 + 2HCl + 16H_3BO_3$.

The ammonia process or bigot process.—Boric acid is produced by heating in a closed vessel 100 parts of colemanite and 150 parts of ammonium sulphate. The product of the first reaction is ammonium borate, which is later decomposed into ammonia and boric acid. The ammonia is condensed and collected, and the boric acid is dissolved from the residuum by leaching with water and concentrating the resultant aqueous solution until crystals of boric acid are formed. The crystals are then removed, washed with water until free from adhering mother liquor, dried, and packed for shipment to the market. At times the crystals are ground to a fine powder before being packed and shipped.

The manufacture of borax from boric acid.—The process generally used to make borax from boric acid is briefly summarized as follows: Equal quantities of crystallized sodium carbonate and water are heated by steam in a lead-lined vessel, and to the solution thus obtained sufficient boric acid is gradually added to combine with the sodium carbonate and form the borax salt $(Na_2B_4O_7), 10H_2O$. Another process is to prepare solu-

tions of ammonia, sodium nitrate, and boric acid in the proportions of two, one, and two, respectively. By heating this mixture and dissolving in water, borax and ammonium nitrate are formed. In both of these cases the crystals of borax are ultimately obtained by the evaporation of the solutions containing the borax salt.

The manufacture of borax from colemanite.—At the borax refinery in Alameda, Cal., the process used to convert colemanite into borax crystals is briefly outlined as follows: The crude colemanite, obtained direct from the mines, is first broken into lumps of from three-fourths to 1½ inches in diameter, then reduced in a grinding mill to the size of fine sand, and finally passed through rolls which grind the material to the fineness of flour. The floured product is transferred to an iron tank partly filled with water containing in solution the proper proportion of sodium carbonate necessary to decompose the calcium borate. (A ready and cheap supply of sodium carbonate is obtained from Owens Lake, Cal.) Heat is applied to the tank and the contents boiled and thoroughly agitated by means of a mechanical agitator. After a short time the chemical reaction has become completed, the double decomposition being the change from calcium borate and sodium carbonate to calcium carbonate and sodium borate. The sodium borate being soluble is extracted from the insoluble calcium carbonate by leaching with hot water, which dissolves in addition a small quantity of other soluble salts from the impurities in the ore and sodium carbonate. As a consequence the crystals of borax obtained by cooling and evaporating this solution in tanks are of a dark color and somewhat impure. They are purified by a second solution in hot water and a second crystallization in a special vat having a series of suspended wires on which the purer borax crystals form. The crystals on the sides and bottom of the vat are less pure. The purified crystals of borax are removed from the vats, washed free from adhering mother liquor, dried, ground, and screened into several grades for the market.

At the Marion (Cal.) works the crude colemanite ore is submitted to a concentration, and the rich concentrates are shipped to the refinery at Bayonne, N. J., for final conversion into borax. These concentrates are in two forms, lumps and fines. Formerly the low grade ores at Marion were rejected, but at the present time they are heated in a two-hearth, 100-ton Holthoff-Wethey furnace, fired by six oil burners. A gentle heat suffices to cause the colemanite in the ore to disintegrate physically into a sand-like product called "flour," which is removed when cold by screening, and is sacked and shipped to the Bayonne refinery. One disadvantage of the separation of the colemanite by heating in a furnace is that any pandermite (the compact variety of the mineral) present in the ore is not affected by the heat, and is consequently left in the waste material remaining in the screens. At times the waste equals in quantity one-half of the "flour" product.

The conversion of the colemanite into borax at the Bayonne refinery in New Jersey is made by decomposing the calcium borate with sodium carbonate, leaching out the sodium biborate with water, yielding a solution which is separated from the insoluble calcium carbonate by passage through a filter press at a pressure of from 50 to 100 pounds per square inch. The clarified solution is transferred to vats having wires suspended from 2-inch iron pipes extending across the top of the vat. The crystals of borax form on these wires as well as on the sides and bottom of the vat, those on the wires being sufficiently pure for all trade requirements, while those on the sides and bottom of the vat have to be redissolved and purified by a second crystallization. The pure crystals are crushed, screened, and sorted into three grades—refined crystals, refined screenings, and granulated borax. The crystals and screenings are packed for the market, but the granulated borax before shipment undergoes a final treatment, which consists of heating in an inclined rotating cylindrical furnace, crushing to the fineness of flour in a pulverizer, settling and collecting the dust in a large dust chamber, and packing the final product for market. The Bayonne refinery is well equipped with all modern mechanical devices for the handling and treatment of the crude and finished materials.

TABLE 6.—*Detailed summary: 1902.*

Number of mines or quarries	6
Number of operators	[1] 6
Character of ownership:	
Incorporated company	6
Salaried officials, clerks, etc.:	
Total number	14
Salaries	$18,128
General officers—	
Number	1
Salaries	$1,800
Superintendents, managers, foremen, surveyors, etc.—	
Number	7
Salaries	$10,598
Foremen below ground—	
Number	3
Salaries	$3,480
Clerks—	
Number	3
Salaries	$2,250
Wage-earners:	
Aggregate average number	153
Aggregate wages	$114,865
Above ground—	
Total average number	76
Total wages	$52,811
Engineers, firemen, and other mechanics—	
Average number	17
Wages	$14,257
Miners or quarrymen—	
Average number	21
Wages	$13,300
All other wage-earners—	
Average number	38
Wages	$25,254
Below ground—	
Total average number	77
Total wages	$62,054
Miners—	
Average number	45
Wages	$37,246
Miners' helpers—	
Average number	27
Wages	$20,550
All other wage-earners—	
Average number	5
Wages	$4,258
Average number of wage-earners at specified daily rates of pay:	
Engineers—	
$1.75 to $1.99	1
$2.00 to $2.24	2
$3.00 to $3.24	1
$3.25 to $3.49	4

[1] Includes operators distributed as follows: California, 4; Nevada, 1; Oregon, 1.

TABLE 6.—*Detailed summary: 1902*—Continued.

Average number of wage-earners at specified daily rates of pay—Con.	
Firemen—	
$2.00 to $2.24	2
$2.75 to $2.99	1
Machinists, blacksmiths, carpenters, and other mechanics—	
$1.50 to $1.74	3
$3.50 to $3.74	2
$4.00 to $4.24	1
Miners or quarrymen—	
$1.50 to $1.74	8
$2.00 to $2.24	11
$2.50 to $2.74	20
$3.00 to $3.24	27
Miners' helpers—	
$2.50 to $2.74	27
All other wage-earners—	
$1.50 to $1.74	11
$1.75 to $1.99	3
$2.00 to $2.24	1
$2.25 to $2.49	13
$2.50 to $2.74	13
$3.00 to $3.24	2
Average number of wage-earners employed during each month:	
Men 16 years and over—	
January	170
February	170
March	174
April	174
May	174
June	96
July	96
August	96
September	168
October	174

TABLE 6.—*Detailed summary: 1902*—Continued.

Average number of wage-earners employed during each month—Con.	
Men 16 years and over—Continued.	
November	174
December	170
Miscellaneous expenses:	
Total	$47,606
Royalties and rent of mine and mining plant	$19,200
Rent of offices, taxes, insurance, interest, and other sundries	$28,406
Cost of supplies and materials	$213,538
Product:	
Total—	
Quantity, short tons	19,142
Value	$2,383,614
Crude—	
Quantity, short tons	2,600
Value	$91,000
Refined—	
Quantity, short tons	16,542
Value	$2,292,614
Power owned:	
Total horsepower	338
Engines—	
Steam—	
Number	5
Horsepower	205
Gas or gasoline—	
Number	11
Horsepower	123
Water wheels—	
Number	1
Horsepower	10
Electric motors—	
Number	1
Horsepower	1

FLUORSPAR

FLUORSPAR.

By Joseph Hyde Pratt.

The mining of fluorspar has increased very greatly since the census of 1890, due to the large increase in the use of this mineral in metallurgical processes, especially in the iron industry. For some years the use of fluorspar for fluxing iron was not large, because it was feared a constant supply could not be obtained. At that time the mineral was produced in only one state, Illinois, although it was known to occur in small quantity in a number of other states. Now, however, it has been proved to occur in commercial quantity in Arizona, Illinois, Kentucky, and Tennessee.

The first census statistics for fluorspar were collected at the Eleventh Census, and these are compared with the statistics for 1902 in the following table:

Table 1.—*Comparative summary: 1902 and 1889.*

	1902	1889
Number of mines	22	(1)
Number of operators	18	(1)
Salaried officials, clerks, etc.:		
Number	42	(1)
Salaries	$27,311	(1)
Wage-earners:		
Average number	269	101
Wages	$110,002	$14,213
Contract work	$300	(1)
Miscellaneous expenses	$23,602	$3,008
Cost of supplies and materials	$31,374	$5,025
Product:[2]		
Quantity, short tons	48,818	9,500
Value	$275,682	$45,855

[1] Not reported.
[2] The United States Geological Survey reports 48,018 short tons, valued at $271,832, which is the product marketed. Census figures represent the product mined.

Less than one-tenth of the total quantity and about one-fifth of the entire value reported for 1902 represent the product prepared at the mine for the market, the preparation consisting of drying and grinding, in addition to the usual washing.

Of the 22 mines in 1902, 14 were in Kentucky, 5 in Illinois, 2 in Arizona, and 1 in Tennessee. The product has increased from 9,500 tons in 1889 to 48,818 tons in 1902, or over fivefold, and the value from $45,835 to $275,682, or over sixfold. In these twelve years, Illinois, which was the only state producing fluorspar commercially in 1889, has increased its production from 9,500 tons, valued at $45,835, to 18,860 tons, valued at $123,000, or 98.5 per cent in amount and 168.4 per cent in value. One mine in Kentucky was reported idle in 1902. At two mines in Illinois development work was done, and the statistics for these are shown in the following statement:

Development work: 1902.

Number of mines	2
Number of operators	2
Wage-earners:	
Average number	5
Wages	$2,125
Cost of supplies and materials	$2,800
Miscellaneous expenses	$25

The 22 productive mines were controlled by 18 operators—2 individuals, 2 firms, and 14 incorporated companies.

Capital stock of incorporated companies.—The details of the capital stock and funded debt authorized and issued by the 14 incorporated companies are shown by states in Table 2.

Table 2.—*Capitalization of incorporated companies: 1902.*

	United States.	Illinois.	Kentucky.	All other states.[1]
Number of incorporated companies	14	3	9	2
Capital stock and bonds issued	$2,214,000	$1,536,000	$628,000	$50,000
Capital stock (all common):				
Total authorized—				
Number of shares	3,146,730	2,500,000	606,630	40,100
Par value	$3,813,000	$2,500,000	$1,263,000	$50,000
Total issued—				
Number of shares	1,726,320	1,536,000	150,220	40,100
Par value	$2,154,000	$1,536,000	$568,000	$50,000
Bonds:				
Authorized—				
Number	1,000	.....	1,000	.....
Par value	$100,000	.....	$100,000	.....
Issued—				
Number	600	.....	600	.....
Par value	$60,000	.....	$60,000	.....

[1] Includes companies distributed as follows: Arizona, 1; Tennessee, 1.

The 9 Kentucky companies issued capital stock to the amount of $568,000 and bonds to the amount of $60,000, making a total of $628,000, which is equivalent to 28.4 per cent of the total capitalization of all companies. The 3 companies in Illinois issued $1,536,000 of capital stock, representing 69.4 of the total capitalization. No dividends were reported on any of the stock and no interest was paid on the bonds.

Employees and wages.—The salaried employees numbered 42, or 13.5 per cent of the 311 salaried employees and wage-earners, and their salaries were $27,311, or 19.9 per cent of the total salaries and wages, which amounted to $137,313. The 269 wage-earners, there-

fore, constituted 86.5 per cent of the total number of employees, and their wages 80.1 per cent of the total salaries and wages.

As shown in Table 4, the busiest months in this industry, all states combined, were from May to December, inclusive. In Illinois, the largest number was employed in August; in Kentucky the maximum was not reached until October, which was true also of "all other states." The average number of wage-earners, at specified daily rates of pay for the different occupations is shown in Table 4. The majority of the miners received from $1.25 to $1.49 per day, 100 miners, or 56.8 per cent of the total number, receiving wages within these limits. For 35 miners, or 19.9 per cent of the total number, the wages were lower, being between $1 and $1.24 per day, while for 41 miners, or 23.3 per cent of the total number, they were higher, 32 miners receiving between $1.50 and $1.74, 5 between $1.75 and $1.99, and 4 between $2 and $2.24. Of the 16 engineers reported in the industry, 14 received between $1.50 and $1.74, and 2 received between $2.50 and $2.74. The rates paid machinists and engineers were, on the whole, higher than those for other wage-earners. The employees at the higher rates, included under "all other wage-earners," are men who wash or jig the ore.

Supplies, materials, and miscellaneous expenses.—The cost of supplies and materials amounted to $31,374, and the miscellaneous expenses were $23,602. The amount included in the latter item for payment of royalties and rent of mines and mining plants was $7,900, or 33.5 per cent of the total; the balance, $15,702, or 66.5 per cent, was paid for rent of offices, taxes, insurance, interest, and other sundries.

Mechanical power.—At the 22 mines, primary power was employed aggregating 669 horsepower, of which 530 or 79.2 per cent was steam, and 139 or 20.8 per cent, gas or gasoline. There was, in addition, one electric motor, with a capacity of 25 horsepower.

Production.—The following table shows the quantity and value of fluorspar produced and sold since 1882:

TABLE 3.—*Production of fluorspar: 1882 to 1902.*

[United States Geological Survey, "Mineral Resources of the United States," 1902.]

YEAR.	Quantity (shorttons).	Value.	Average value.	YEAR.	Quantity (shorttons).	Value.	Average value.
1882....	4,000	$20,000	$5.00	1893...	12,400	$84,000	$6.77
1883....	4,000	20,000	5.00	1894...	7,500	47,500	6.33
1884....	4,000	20,000	5.00	1895...	4,000	24,000	6.00
1885....	5,000	22,500	4.50	1896...	6,500	52,000	8.00
1886....	5,000	22,000	4.40	1897...	5,062	37,159	7.34
1887....	5,000	20,000	4.00	1898...	7,675	63,050	8.21
1888....	6,000	30,000	5.00	1899...	15,900	96,050	6.08
1889....	9,500	45,835	4.83	1900...	18,450	94,500	5.12
1890....	8,250	55,328	6.71	1901...	19,586	113,803	5.81
1891....	10,044	78,330	7.80	1902...	48,018	271,832	5.66
1892....	12,250	89,000	7.27				

From 1882 up to 1887, the annual production of fluorspar was only 4,000 or 5,000 tons. In the next few years the production increased considerably, reaching 12,400 tons in 1893. Then it fell off to 7,500 tons in 1894 and to 4,000 tons in 1895, thus reaching the figure at which it stood in the years 1882 to 1884. The year 1896 marked the beginning of a second period of increasing production, which appears to be still in progress. In 1899 the production was 15,900 tons, which was more than double that of the preceding year. But the most remarkable increase was in the year 1902, when the quantity produced showed a gain of 28,432 tons, or 145.2 per cent over that of the preceding year, and the value of the product, a gain of $158,029, or 138.9 per cent.

The average value of fluorspar per ton has varied from $4 to $8. The average was exceptionally high in the years 1896 to 1898, inclusive, reaching $8.21 in 1898. In 1902 it was $5.66; the prices reported for that year varied from $2.86 to $11.50 per ton, this higher value being obtained for the fluorspar mined in Arizona, which was used in California. This increase is due to fluorspar being much more largely used than formerly in the fluxing of iron in steel works, and as it is introduced into the smelting of copper and the reduction of other metals, there should be a still further increase in its production.

The imports of fluorspar are not separately stated in the records of the Bureau of Statistics of the Department of Commerce and Labor, but are included with minerals and oils not elsewhere specified.

The detailed statistics of the fluorspar industry for 1902 are shown in Table 4.

DESCRIPTIVE.

Occurrence and use.—Fluorspar is the common name of fluoride of calcium, a mineral occurring in crystals and masses of various colors, very commonly as the gangue of many metallic ores, especially of lead. It is found chiefly in veins in limestone, sandstone, mica slate, clay slate, and gneiss. When it occurs in commercial quantity, it is usually in cleavable masses, and of white, greenish white, or pale green color; but when small openings exist in the veins, the fluorspar is apt to be found in well-developed cubical crystals, which are generally highly colored with various tints of purple, indicating that it is associated with metallic minerals.

Until 1898 the only sources of fluorspar in the United States were the mines in Hardin and Pope counties, in southern Illinois, but during that year deposits were opened in Livingston and Crittenden counties, Ky., and in 1900 in Smith, Trousdale, and Wilson counties, Tenn., and in Yuma county, Ariz. As has been shown above, all these states were producers of fluorspar in commercial quantity in 1902. The mineral has been found widely distributed throughout the United States, but thus far it is only in the four states mentioned that it has been found in sufficient quantity for commercial purposes.

In the fluorspar deposits of Illinois and Kentucky there is known to be a very large supply of this mineral, capable of meeting the demand for many years.

As this overcomes one of the objections often advanced against using fluorspar in the smelting of iron, namely, that a constant supply of this mineral could not be depended upon, its use for this purpose should now increase rapidly. Other hindrances to the use of fluorspar for fluxing purposes have been the higher cost of this flux as compared with limestone, inaccessibility of the deposits, and the action of the slag and gases on the lining of the furnaces. But the recently discovered deposits of Kentucky and Tennessee, together with the deposits in Illinois, furnish an abundant supply, favorably located for transportation, either by railroad or water. The use of chromite (chromic iron ore), either in mineral form or as chrome bricks, will make a lining for furnaces which can be affected but little by the use of fluorspar as a flux. Fluorspar possesses qualities that make it especially adapted for the fluxing of iron, and these should more than compensate for its higher cost, as compared with limestone. Thus far the larger proportion of the fluorspar mined has been used in steel works. Very little is used in blast furnaces or in the smelting of copper or other metals; for these purposes, and also in foundry work, its use will undoubtedly increase rapidly when its value as a flux is more thoroughly understood.

Another use of fluorspar, and formerly its chief use, is in the preparation of hydrofluoric acid. At the present time it is estimated that only from 5 to 10 per cent of the product is used for this purpose. The mineral is also used in the manufacture of opalescent glass, being considered very essential for this purpose.

TABLE 4.—DETAILED SUMMARY: 1902.

	United States.	Illinois.	Kentucky.	All other states and territories.[1]
Number of mines	22	5	14	3
Number of operators	18	5	10	3
Character of ownership:				
Individual	2	1	.....	1
Firm	2	1	1	.....
Incorporated company	14	3	9	2
Salaried officials, clerks, etc.:				
Total number	42	9	31	2
Total salaries	$27,311	$5,304	$21,107	$900
General officers—				
Number	12	1	11	.....
Salaries	$11,545	$300	$11,245	.....
Superintendents, managers, foremen, surveyors, etc.—				
Number	17	3	12	2
Salaries	$12,437	$3,500	$8,037	$900
Foremen, below ground—				
Number	11	3	8	.....
Salaries	$2,849	$1,024	$1,825	.....
Clerks—				
Number	2	2	.....	.....
Salaries	$480	$480	.....	.....
Wage-earners:				
Aggregate average number	269	71	193	5
Aggregate wages	$110,002	$28,845	$79,107	$2,050
Above ground—				
Total average number	140	38	98	4
Total wages	$56,295	$15,328	$39,407	$1,500
Engineers, firemen, and other mechanics—				
Average number	25	5	20	.....
Wages	$12,626	$2,481	$10,145	.....
Miners—				
Average number	56	4	48	4
Wages	$21,180	$1,275	$18,405	$1,500
Boys under 16 years—				
Average number	2	.....	2	.....
Wages	$234	.....	$234	.....
All other wage-earners—				
Average number	57	29	28	.....
Wages	$22,195	$11,572	$10,623	.....
Below ground—				
Total average number	129	33	95	1
Total wages	$53,767	$13,517	$39,700	$550
Miners—				
Average number	120	24	95	1
Wages	$50,504	$10,254	$39,700	$550
Miners' helpers—				
Average number	9	9	.....	.....
Wages	$3,263	$3,263	.....	.....
Average number of wage-earners at specified daily rates of pay:				
Engineers—				
$1.50 to $1.74	14	2	12	.....
$2.50 to $2.74	2	1	1	.....
Firemen—				
$1.00 to $1.24	1	.....	1	.....
$1.25 to $1.49	1	1	.....	.....
$2.00 to $2.24	2	.....	2	.....
Machinists, blacksmiths, carpenters, and other mechanics—				
$1.50 to $1.74	2	1	1	.....
$2.50 to $2.74	1	.....	1	.....
$3.00 to $3.24	2	.....	2	.....
Average number of wage-earners at specified daily rates of pay—Continued.				
Miners—				
$1.00 to $1.24	35	5	28	2
$1.25 to $1.49	100	12	88	.....
$1.50 to $1.74	32	7	25	.....
$1.75 to $1.99	5	1	2	2
$2.00 to $2.24	4	3	.....	1
Miners' helpers—				
$1.00 to $1.24	1	1	.....	.....
$1.25 to $1.49	8	8	.....	.....
Boys under 16 years—				
$0.75 to $0.99	2	.....	2	.....
All other wage-earners—				
$1.00 to $1.24	2	1	1	.....
$1.25 to $1.49	45	25	20	.....
$1.50 to $1.74	3	.....	3	.....
$2.00 to $2.24	7	3	4	.....
Average number of wage-earners employed during each month:				
Men 16 years and over—				
January	161	58	103	.....
February	147	51	96	.....
March	147	49	98	.....
April	183	60	123	.....
May	255	66	186	3
June	280	67	210	3
July	333	88	243	2
August	340	89	243	8
September	354	85	259	10
October	375	83	280	12
November	336	76	249	11
December	293	80	202	11
Boys under 16 years—				
July	4	.....	4	.....
August	4	.....	4	.....
September	4	.....	4	.....
October	4	.....	4	.....
November	4	.....	4	.....
December	4	.....	4	.....
Contract work:				
Amount paid	$300	.....	$300	.....
Number of employees	3	.....	3	.....
Miscellaneous expenses:				
Total	$23,602	$1,149	$22,328	$125
Royalties and rent of mine and mining plant	$7,900	$250	$7,650	.....
Rent of offices, taxes, insurance, interest, and other sundries	$15,702	$899	$14,678	$125
Cost of supplies and materials	$31,374	$17,115	$13,952	$307
Product:				
Quantity, short tons	48,818	18,860	29,030	928
Value	$275,682	$123,000	$143,410	$9,272
Power owned:				
Total horsepower	669	162	507	.....
Engines—				
Steam—				
Number	17	6	11	.....
Horsepower	530	162	368	.....
Gas or gasoline—				
Number	10	.....	10	.....
Horsepower	139	.....	139	.....
Electric motors—				
Number	1	.....	1	.....
Horsepower	25	.....	25	.....

[1] Includes operators distributed as follows: Arizona, 2; Tennessee, 1.

GYPSUM

GYPSUM.

By Story B. Ladd.

The statistics presented herewith comprise those for gypsum in its calcined form as well as in its natural state. The chief consumption of gypsum is for the manufacture of plaster of Paris and wall or cement plaster, of which plaster of Paris is the chief ingredient. At the Tenth Census no statistics in regard to gypsum were reported, and at the three decades prior thereto, namely, 1870, 1860, and 1850, only the manufacturing statistics for plaster are available for purposes of comparison. Table 1 is a comparative summary for the years 1850, 1860, 1870, 1889, and 1902.

Table 1.—*Comparative summary: 1850 to 1902.*

	1902	1889	1870	1860	1850
Number of mines or quarries	62	(1)	(1)	(1)	(1)
Number of operators	45	(1)	[2]321	[2]307	[2]140
Salaried officials, clerks, etc.:					
Number	249	(3)	(3)	(3)	(3)
Salaries	$300,420	(3)	(3)	(3)	(3)
Wage-earners:					
Average number	1,472	761	1,513	866	381
Wages	$759,258	$249,200	$533,407	$232,500	$100,692
Contract work	$406	$10,031	(1)	(1)	(1)
Miscellaneous expenses	$200,769	$45,262	(1)	(1)	(1)
Cost of supplies and materials	$341,760	$128,854	$1,430,140	$522,836	$239,063
Product[4]:					
Quantity, short tons	681,633	246,725	(1)	(1)	(1)
Value	$2,089,341	$764,118	$2,691,851	$1,110,854	$428,914

[1] Not reported.
[2] Establishments.
[3] Not reported separately.
[4] The United States Geological Survey reports 816,478 short tons of crude gypsum, of the value as here given. The Census figures of quantity are for the product prepared, in greatest part, for the market.

In 1850 the value of the land-plaster product was given as $428,914. In 1860 the value of plaster and its manufactures was $1,110,854, and presumably the largest portion of this amount was land plaster. In 1870 the amount of plaster manufactured, reported as "Plaster, ground," and presumably chiefly used for land plaster, reached $2,691,851. Up to this time there appears to have been a steady growth in the use of gypsum as a fertilizer, but with the development of the phosphate rock industry, which began just prior to the close of the decade ending in 1870, came a corresponding reduction in the use of gypsum for land plaster, and in 1880 the total gypsum production, as reported by the United States Geological Survey, was but 90,000 short tons, valued at $400,000.

The mining of phosphate rock commenced in South Carolina in 1867, and in 1870 the production was 65,241 long tons. In 1880 the sales of phosphate rock in the United States amounted to 211,377 long tons, valued at $1,123,823, while the gypsum product had fallen, as above noted, to a value of $400,000. In 1889 the sales of phosphate rock were 550,245 long tons, valued at $2,937,776. Florida had lately become a producer. On the other hand, the ground gypsum sold as land plaster in 1889 was but 108,771 short tons, valued at $233,307, in contrast with the production for 1870 of ground plaster, valued at $2,691,851.

The shrinkage in the consumption of gypsum for land plaster continues, the growth in the gypsum industry since 1889 being due to the increasing use of wall or cement plaster. In 1889, 108,771 tons, or 40.6 per cent, of the gypsum was sold as land plaster; in 1902 only 60,791 tons, or 7.4 per cent.

The growth of the industry during the period 1889 to 1902 has been entirely in the production of calcined gypsum. In 1889, 85,755 tons of gypsum, or 32 per cent of the amount quarried, were calcined, while in 1902 the quantity calcined was 674,232 tons, or 82.6 per cent of the gypsum quarried, producing 539,387 tons of calcined plaster products—plaster of Paris and wall or cement plaster. Along with the increased consumption of calcined plaster there was a decrease in the average price from $6.92 per ton in 1889 to $3.50 per ton in 1902. There was no material change in the average price of crude gypsum, it being $1.13 per ton in 1889 and $1.15 per ton in 1902. The average value of the land plaster, however, decreased from $2.14 per ton in 1889 to $1.75 per ton in 1902.

A change in the character of the industry is also shown by the reduction in the number of operators. In 1870, 321 operators were reported, and in 1902 only 45. The number of mines, which in 1870 must have been at least 321—that being the number of operators—was only 62 in 1902. The production of land plaster requires small capital, the gypsum being simply mined or quarried and ground; and the average values of the product per operator for the years 1850, 1860, and 1870—$3,064, $3,910, and $8,386, respectively—indicates that during that earlier period, when land

plaster was the principal or sole product, this industry was small and local in character. The statistics for 1902 show a concentration of the business. The 62 producing mines or quarries were controlled by 45 operators and the average value of the product per operator was $46,430. Of the 62 active mines or quarries, 19 were operated by 2 companies. The reduction in the number of operators and active mines or quarries reflects the growth of the wall plaster industry, which has a wider market and requires a much larger capital and plant than the mere manufacture of land plaster.

During the period from 1889 to 1902, the value of the product increased 173.4 per cent, the wage-earners 93.4 per cent, and the amount paid in wages 204.7 per cent.

There were 17 idle mines or quarries in 1902, distributed as follows: 8 in New York, 3 in Arizona, and 1 each in Kansas, Missouri, New Mexico, Ohio, Texas, and Virginia. These were owned by 9 individuals, 1 firm, and 5 incorporated companies. Two of the mines in Arizona were owned by 1 individual. Two of the other idle mines, 1 in Kansas and 1 in Missouri, were owned by 1 corporation, which operated 16 active mines or quarries in Iowa, Kansas, Michigan, New York, Ohio, and Oklahoma. The statistics of the capitalization of this corporation are included among those of the active mines. The remaining 4 incorporated companies were located 1 each in New York, New Mexico, Ohio, and Texas. Three of these did not report capitalization. The fourth company reported an authorized capital stock of 250,000 shares, with a par value of $250,000; all of the common stock, 200,000 shares of a par value of $200,000, had been issued. It reported also authorized bonds of a par value of $25,000, of which $15,000 had been issued, making a total of $215,000 for stocks and bonds issued.

Of the 45 operators in 1902, 13 were individuals, 6 were firms, and 26 were incorporated companies. Only 3.6 per cent of the gypsum mined or quarried was produced by the 19 individuals and firms, and in Iowa, Kansas, Michigan, Oklahoma, Texas, and Utah the operators were solely incorporated companies.

Capital stock of incorporated companies.—Table 2 presents the details of the capitalization of the incorporated companies.

TABLE 2.—CAPITALIZATION OF INCORPORATED COMPANIES: 1902.

	United States.	Kansas.	Michigan.	New York.	Oklahoma.	All other states.
Number of incorporated companies	26	5	[1]4	6	3	[2]8
Number reporting capitalization	25	5	4	6	3	7
Capital stock and bonds issued	$10,670,965	$245,765	$8,157,500	$659,800	$260,000	$1,347,900
Capital stock:						
Total authorized—						
Number of shares	106,880	1,821	83,100	5,540	2,600	13,819
Par value	$10,576,665	$220,765	$8,160,000	$554,000	$260,000	$1,381,900
Total issued—						
Number of shares	106,298	1,821	83,000	5,398	2,600	13,479
Par value	$10,525,965	$220,765	$8,157,500	$539,800	$260,000	$1,347,800
Dividends paid	$64,300	$3,126	$35,700	.....	$2,400	$23,074
Common—						
Authorized—						
Number of shares	61,580	1,821	38,100	5,240	2,600	13,819
Par value	$6,046,665	$220,765	$3,660,000	$524,000	$260,000	$1,381,900
Issued—						
Number of shares	60,998	1,821	38,000	5,098	2,600	13,479
Par value	$5,995,965	$220,765	$3,657,500	$509,800	$260,000	$1,347,800
Dividends paid	$64,300	$3,126	$35,700	.....	$2,400	$23,074
Preferred—						
Authorized—						
Number of shares	45,300	.....	45,000	300	.....	.....
Par value	$4,530,000	.....	$4,500,000	$30,000	.....	.....
Issued—						
Number of shares	45,300	.....	45,000	300	.....	.....
Par value	$4,530,000	.....	$4,500,000	$30,000	.....	.....
Bonds:						
Authorized—						
Number	1,645	25	1,500	120	.....	.....
Par value	$1,145,000	$25,000	$1,000,000	$120,000	.....	.....
Issued—						
Number	145	25	.....	120	.....	.....
Par value	$145,000	$25,000	.....	$120,000	.....	.....
Interest paid	$2,700	$1,500	.....	$1,200	.....	.....
Assessments levied	$3,240	.....	.....	$3,240	.....	.....

[1] One of these companies operated mines and quarries in Iowa, Kansas, New York, Ohio, and Oklahoma, as well as in Michigan.
[2] Includes companies distributed as follows: Iowa, 3; Texas, 2 (1 company operating quarries also in Oklahoma and Wyoming); Utah, 1; Virginia, 1; Wyoming, 1.

Of the 26 incorporated companies, 6 were in New York, 5 in Kansas, 4 in Michigan, 3 each in Iowa and Oklahoma, 2 in Texas, and 1 each in Utah, Virginia, and Wyoming. These companies operated 43 mines or quarries distributed as follows: 9 in Iowa, 8 in New York, 7 in Kansas, 6 in Michigan, 5 in Oklahoma, 2 each in Ohio, Texas, and Wyoming, and 1 each in Utah and Virginia. The capitalization was reported for all of the incorporated companies, with the exception of 1 company in Iowa not engaged exclusively in the mining or quarrying of gypsum and the manufacture of its products. The authorized capital stock consisted of 61,580 shares of common stock of a par value of $6,046,665, and 45,300 shares of preferred stock of a par value of $4,530,000; at the close of the year covered by this investigation, 60,998 shares of common stock of a par value of $5,995,965, and all of the preferred stock had been issued. The authorized bonded indebtedness comprised 1,645 bonds of a par value of $1,145,000, of which there had been issued 145 bonds of a par value

of $145,000. The outstanding capital stock and bonds issued aggregated $10,670,965.

The interest paid on the bonded debt was $2,700; the small amount is explained by the fact that the organization of several of the companies occurred during 1902, and only 2 companies reported the payment of interest on bonds aggregating $45,000. Dividends amounting to $64,300 were paid by 6 companies, distributed 1 each in Iowa, Kansas, Michigan, Oklahoma, Texas, and Utah. The capitalization of 1 company operating mines or quarries in Iowa, Kansas, Michigan, New York, Ohio, and Oklahoma was credited to Michigan, as its largest production was from that state; and, in like manner, the capitalization of 1 company operating mines or quarries in Oklahoma, Texas, and Wyoming was credited to Texas, where its largest plant was located.

Employees and wages.—Of the total amount, $1,059,678, reported as paid for salaries and wages, $759,258, or 71.6 per cent, was paid to the wage-earners, and $300,420, or 28.4 per cent, to the salaried employees.

The variation in the number of wage-earners employed at different seasons of the year is shown in Table 6, which gives the average number of men and boys employed during each month. The employment of boys under 16 is reported only in the case of 1 mine. The least average number of wage-earners employed during any month was 773 in January, and the largest average number for any month was 1,696 in September. For the remaining months the number fluctuated within a comparatively narrow range. The number of wage-earners employed at specified daily rates of pay is also shown in Table 6.

The prevailing rate of pay for wage-earners was from $1.50 to $1.74 per day, 754, or 51.2 per cent, receiving this rate. The per cent receiving less than $1.25 per day was only 2.5; 5.6 per cent received from $1.25 to $1.49; 23 per cent, from $1.75 to $1.99; 10.2 per cent, from $2 to $2.24; 3.3 per cent, from $2.25 to $2.49; 2.5 per cent, from $2.50 to $2.74; and 1.7 per cent received $3 and over. Of the total number of wage-earners 614, or 41.7 per cent, were classed as miners or quarrymen. Of these 329, or 22.4 per cent, received from $1.50 to $1.74 per day. Nine received from $3 to $3.24 per day.

Mining and quarrying on a tonnage basis was reported by 18 mines or quarries, at rates ranging from a minimum of $0.20 per ton to a maximum of $0.65 per ton, with an average of $0.445 per ton. These mines or quarries were distributed as follows: 7 in Iowa, 4 in New York, 2 in Kansas, and 1 each in California, Michigan, Oklahoma, Texas, and Utah.

Supplies, materials, and miscellaneous expenses.—The total amount reported for supplies and materials was $341,760. In the case of operators producing uncalcined gypsum only, either crude gypsum or land plaster, the expense for supplies and materials was small, only 5 or 10 cents per ton.

The total amount reported for miscellaneous expenses was $200,769, of which amount $49,912 was paid by 20 mines or quarries for royalties and rent of mine and mining plant; and $150,857 for rent of offices, taxes, insurance, interest, and other sundries. The mines or quarries reporting the payment of royalties and rent of mine and mining plant were distributed as follows: Six in New York, 4 in Kansas, 2 each in Iowa, Ohio, Oklahoma, and Wyoming, and 1 each in Texas and Virginia.

Mechanical power.—Of the 62 mines or quarries operated, 55 reported power, the primary power employed aggregating 7,319 horsepower. Where mills were operated in conjunction with the mine or quarry, this includes mill power as well as power directly employed in mining or quarrying. The power was supplied by 68 steam engines, aggregating 6,385 horsepower; 2 gas or gasoline engines with a total of 20 horsepower; and 11 water wheels having 914 horsepower. There were, in addition, 5 electric motors with a capacity of 68 horsepower.

Production.—The total production for the year 1902 was 816,478 short tons of gypsum quarried, of which 674,232 tons were calcined, producing 539,387 tons of calcined plaster—plaster of Paris and wall or cement plaster—valued at $1,889,190. There were sold in the crude state 81,455 tons of gypsum, valued at $93,914, an average price of $1.15 per ton; and 60,791 tons ground for land plaster, valued at $106,237, an average price of $1.75 per ton. The 539,387 tons of calcined products comprised 188,702 tons of plaster of Paris, valued at $562,928, an average price of $2.98 per ton; and 350,685 tons of wall or cement plaster, valued at $1,326,262, an average price of $3.78 per ton. The production of the 188,702 tons sold as plaster of Paris consumed 235,878 tons of crude gypsum; and the production of the 350,685 tons of wall or cement plaster consumed 438,354 tons of gypsum before calcination into plaster of Paris and manufacture into wall or cement plaster. The increase in the marketable gypsum products for 1902 over those of 1889 was in quantity 434,908 tons, or 63.7 per cent, and in value $1,325,223, or 173.4 per cent.

Of the calcined products 65.3 per cent was wall or cement plaster, including all of the calcined product from the states of Nevada, South Dakota, and Utah; 90 per cent and over of that from California, Kansas, Montana, Oklahoma, Texas, and Wyoming; from 80 to 90 per cent of that from Iowa and Oregon; 60 per cent of that from Colorado, and less than 50 per cent only from Michigan, New York, Ohio, and Virginia.

Table 3 shows the production of gypsum in the United States from 1880 to 1902, as reported by the United States Geological Survey.

TABLE 3.—*Production of gypsum: 1880 to 1902.*

[United States Geological Survey, "Mineral Resources of the United States," 1901 and 1902.]

YEAR.	Quantity of gypsum (short tons).	Value of products; crude, land plaster, and calcined.	YEAR.	Quantity of gypsum (short tons).	Value of products; crude, land plaster, and calcined.
1880	90,000	$400,000	1892	256,259	$695,492
1881	85,000	350,000	1893	253,615	696,615
1882	100,000	460,000	1894	239,312	761,719
1883	90,000	420,000	1895	265,503	797,447
1884	90,000	390,000	1896	224,254	573,344
1885	90,405	405,000	1897	288,982	755,864
1886	95,250	428,625	1898	291,638	755,280
1887	95,000	425,000	1899	486,235	1,287,080
1888	110,000	550,000	1900	594,462	1,627,203
1889	[1] 267,769	764,118	1901	633,791	1,506,641
1890	182,995	574,523	1902	[2] 816,478	2,089,342
1891	208,126	628,051			

[1] Marketable products, 246,725 short tons.
[2] Marketable products, 681,633 short tons.

Beginning with the year 1899 there was shown a marked annual increase in the quantity of gypsum produced. The increase in 1899 was 66.7 per cent; in 1900, 22.3 per cent; in 1901, 12 per cent; and 1902, 24 per cent. The total increase from 1898 to 1902 was 524,840 tons, or 180 per cent.

The imports of gypsum from 1889 to 1902 are shown in the following table:

TABLE 4.—*Gypsum imported into the United States: 1889 to 1902.*

[United States Geological Survey, "Mineral Resources of the United States," 1902.]

YEAR ENDING—	GROUND OR CALCINED.		UNGROUND.		Value of manufactured plaster of Paris.	Total value.
	Quantity (long tons).	Value.	Quantity (long tons).	Value.		
December 31—						
1889	5,466	$40,291	170,965	$179,849	(1)	$220,140
1890	7,568	55,250	171,289	174,609	(1)	229,859
1891	9,560	97,316	110,257	129,003	(1)	226,319
1892	6,832	75,608	181,104	232,403	(1)	308,011
1893	3,363	31,670	164,300	180,254	(1)	211,924
1894	2,027	16,823	162,500	179,237	(1)	196,060
1895	3,295	21,526	192,549	215,705	$10,352	247,583
1896	3,292	21,982	180,269	193,544	11,722	227,248
1897	2,664	17,028	163,201	178,686	16,715	212,429
1898	2,973	18,501	166,066	181,364	40,979	240,844
1899	3,265	19,250	196,579	220,603	58,073	297,996
1900	3,109	19,179	209,881	229,878	66,473	315,530
1901	3,106	19,627	235,204	238,440	68,603	326,670
1902	3,647	23,225	305,367	284,942	52,533	360,700

[1] Not specified.

The world's production of gypsum from 1893 to 1902, inclusive, is shown in the following table:

TABLE 5.—THE WORLD'S PRODUCTION OF GYPSUM: 1893 TO 1902.

[United States Geological Survey, "Mineral Resources of the United States," 1902.]

YEAR.	UNITED STATES.		FRANCE.		CANADA.		GREAT BRITAIN.		GERMAN EMPIRE.		ALGERIA.		INDIA.		CYPRUS.	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.	Quantity (short tons).	Value.
1893	253,615	$696,615	.....	.....	192,568	$196,150	158,122	$287,940	.....	.....	.....	.....	.....	.....	2,357	$6,625
1894	239,312	761,719	1,693,881	$2,891,365	223,631	202,031	169,102	321,822	.....	.....	36,355	$114,900	3,548	$1,566	3,104	9,006
1895	265,503	797,447	2,175,448	3,392,768	226,178	202,608	196,037	348,400	23,994	$11,040	50,127	133,226	7,511	2,987	2,093	5,252
1896	224,254	573,344	1,866,498	2,661,200	207,032	178,061	213,028	361,509	31,736	14,598	41,350	114,361	8,248	3,130	1,050	2,590
1897	288,982	755,864	1,845,874	2,673,033	239,691	244,531	203,151	325,513	28,821	13,228	40,510	109,648	9,025	3,333	4,167	8,162
1898	291,638	755,280	1,931,712	2,777,816	219,256	230,440	219,549	345,882	28,315	13,166	41,156	110,660	9,249	1,503	4,279	7,551
1899	486,235	1,287,080	1,802,812	2,641,020	244,566	257,329	238,071	372,073	32,760	19,660	44,037	117,895	7,216	768	4,402	8,866
1900	594,462	1,627,203	1,761,835	2,772,221	252,001	259,009	233,002	348,210	39,103	17,199	41,446	139,190	4,865	424	.....	.....
1901	633,791	1,506,641	2,182,229	3,449,747	293,879	340,148	224,919	344,650	[1] 35,013	[1] 23,139	38,955	132,286	(2)	(2)	.....	.....
1902	816,478	2,089,341	(2)	(2)	382,045	356,317	251,615	(2)	(2)	(2)	(2)	(2)	(2)	(2)	.....	.....

[1] Includes Baden.

[2] Not yet available.

The detailed statistics for the gypsum industry during 1902 are given in Table 6.

DESCRIPTIVE.

Gypsum, a natural product, is calcium sulphate, of the chemical formula $CaSO_4.2\,H_2O$, containing 46.5 per cent of sulphuric acid, 32.6 per cent of lime, and 20.9 per cent of water. Anhydrite, a mineral like gypsum, but, as its name indicates, containing no water, is composed of 58.8 per cent of sulphuric acid and 41.2 per cent of lime. This absorbs water and changes to gypsum. When gypsum is properly calcined it loses a part of the water of its composition and becomes plaster of Paris, the name originating from the great deposits of gypsum worked at Montmartre, a suburb of Paris. The transparent crystallized variety of gypsum is called selenite; its fine massive variety, alabaster; and its fibrous form, satin spar. A loose earthy gypsum found in Kansas and other points in the West is called gypsite.

Gypsum crystallizes in the monoclinic system, has a hardness of 2, and a specific gravity of 2.31. Its color is usually white, although sometimes red, green, blue, gray, or brown. When protected from the action of water it is extremely durable, as evidenced by the numerous monumental effigies, many centuries old, in European churches and elsewhere.

It is quite generally distributed and occurs in irregular and often in very extensive and massive deposits. A deposit of white crystalline gypsum at Netherfield, England, is more than 50 feet in thickness, and in the Thüringerwald, Germany, a great mass has been sunk through to a depth of 70 feet. The gypsum deposits of Onondaga county, N. Y., show in places a thickness of 60 feet. The snow-white alabaster found at Volterra,

in Tuscany, Italy, is used extensively at Florence and Leghorn for works of art. It is white when newly broken and on drying becomes even whiter on the surface. It is easily cut and turned and under proper treatment takes a fine polish and satin luster.

Origin.—Gypsum deposits have been formed by direct deposition, and by the alteration of existing lime deposits. Most of the gypsum deposits of the world are considered to have been formed by the evaporation and concentration of sea water, although the calcium sulphate is not deposited until about 80 per cent of the water has been evaporated. Sea water, according to the analyses in the Challenger Reports, contains 3.5 per cent of mineral matter of the following constituents:

	Per cent.
Sodium chloride (salt)	77.758
Magnesium chloride	10.878
Magnesium sulphate	4.737
Calcium sulphate (gypsum)	3.600
Potassium sulphate	2.465
Calcium carbonate	0.345
Magnesium bromide	0.217
	100.000

When such a body of water cut off from the ocean is evaporated, the calcium sulphate is deposited before the sodium chloride, the latter being thrown down only after the removal of 93 per cent of the water. With complete evaporation and deposition there would be, therefore, first a deposit of gypsum and then a heavy deposit of salt, though the evaporation may go far enough to deposit the gypsum, but not far enough to deposit the salt; or if the latter be deposited it may be removed subsequently by solution. Gypsum deposits, therefore, are more widely spread than salt, but usually occur in thinner beds.

When sulphuric acid, liberated by the decomposition of pyrite, acts on calcium carbonate and converts it into calcium sulphate, there is generally a gradual transition from the limestone into the gypsum rock.

Gypsum is deposited by some thermal springs, as in Iceland, where the sulphurous acids on becoming oxidized change to sulphuric acid, which converts the calcium carbonate into calcium sulphate, and this when evaporation takes place is deposited in fibrous and crystalline forms.

The theory of Dawson on the origin of gypsum at Plaister Cove, Nova Scotia, is as follows: First, there was an accumulation of numerous thin layers of limestone, either so rapidly or at such great depths that organic remains were not included in any but the upper layers. Second, there was an introduction of sulphuric acid, in solution or in vapor, which was a product of volcanic action. Then for a long time the acid waters acted upon the calcareous material without interruption from mechanical detritus, changing the calcium carbonate to calcium sulphate, and gypsum of good quality accumulated in considerable thickness.

Occurrence.—Gypsum is widely distributed geologically, being found in various formations ranging from the Silurian up to the Tertiary. In New York extensive beds of gypsum are found in the Silurian formation; in Ohio and Michigan they occur in the Carboniferous; and in Iowa and Kansas they are Cretaceous.

Gypsum is also widely distributed geographically. In the United States it is found in Arizona, California, Colorado, Iowa, Kansas, Michigan, Montana, Nevada, New Mexico, New York, Ohio, Oklahoma, Oregon, South Dakota, Texas, Utah, Virginia, and Wyoming, and is mined in all these states except Arizona, Missouri, and New Mexico. It is found in Arabia, Austria, Bohemia, Canada, Egypt, England, France, Germany, Italy, Norway, and Persia.

Use.—The use of gypsum was known at a very early period, for the Greeks were familiar with it, as shown by the writings of Theophrastus and Pliny. Gypsum in its ground, uncalcined state is used chiefly for land plaster, a fertilizer. In its calcined form, as plaster of Paris, it has extensive and varied uses.

Land plaster.—Ground plaster has long been used as a fertilizer. Virgil wrote concerning the value of gypsum on cultivated lands. Benjamin Franklin called attention to the value of gypsum as a fertilizer for grass by sowing land plaster in a clover field, so as to form the sentence, "This has been plastered with gypsum," the letters showing by the height and color of the clover where gypsum had been sown.

Numerous experiments and tests are on record as to the value of gypsum as a fertilizer. Boussingault in 1841 fertilized a clover field with gypsum and analyzed the clover grown on fertilized and on unfertilized land. These experiments were conducted for two years on the same land, and the analyses of the ash of the clover from a hectare of ground showed as follows, in kilograms:

Analyses of clover.[1]

	1841		1842	
	Land with gypsum.	Land without gypsum.	Land with gypsum.	Land without gypsum.
Ashes free from CO_2	270.0	113.0	280.0	97.0
Silica	28.1	22.7	10.4	12.7
Oxide (iron, manganese, alumina)	2.7	1.4	(?)	0.6
Lime	79.4	32.2	102.8	32.2
Magnesia	18.1	8.6	28.5	7.1
Potash	95.6	26.7	97.2	28.6
Soda	2.4	1.4	0.8	2.8
Sulphuric acid	9.2	4.4	9.0	3.0
Phosphoric acid	24.2	11.0	22.9	7.0
Chlorine	10.3	4.6	8.4	3.0

[1] The University Geological Survey of Kansas, Vol. V, Report on Gypsum and Gypsum Cement Plasters.

This shows an increase in all the mineral constituents, but especially in lime, magnesia, and potash.

The theories of the action of gypsum as a fertilizer have been many. Sir Humphry Davy and others before and after his time have regarded gypsum as a direct source of plant food. It is now thought that gypsum acts as a fertilizer in three ways, one mechanical and two chemical:

(1) The gypsum by mechanical action flocculates loose soils.

(2) Gypsum as pointed out by Storer[1] has nearly one-half its weight in oxygen and gives this up to many substances, and so may act upon nitrogenous and carboniferous substances in the soil.

(3) Gypsum decomposes the double silicates in the earth, setting free potash as a soluble silicate. According to Storer, the action is as follows:

$$\left.\begin{matrix}Al_2O_3\\CaO\\K_2O\\H_2O\end{matrix}\right\}XSiO_2 + CaOSO_3 = \left\{\begin{matrix}Al_2O_3\\CaO\\CaO\\H_2O\end{matrix}\right\}XSiO_2 + K_2OSO_3$$

By this means the potash in solution reaches the roots of the plants. Soils with abundant potash do not need land plaster, and soils with no potash compounds are not benefited in this respect by it.

Plaster of Paris.—The phenomena attendant upon the baking and hardening of plaster of Paris were first studied by Lavoisier. In the Comptes Rendus of February 17, 1765, appears the following: "After having removed the water of hydration from gypsum by heat, if it be presented to it again (this is commonly known as the mixing or tempering of plaster), it takes it back with avidity, and suddenly assumes a state of irregular crystallization; the small crystals which form become confused with each other, the result being a very hard mass." Lavoisier discovered that when plaster was baked at too high a temperature it lost its peculiar property of setting, and that when it was heated the water of crystallization was removed at two different stages, three-fourths of it being much more easily removed than the remainder. Payen, in 1830, found that gypsum began to lose its water of crystallization at 115° C., and that the loss increased rapidly as the temperature rose. He concluded that a temperature of from 110° to 120° C. was the best for calcination, but that plaster of Paris could be made at a lower temperature, even as low as 80° C., if the burning were continued long enough. He found that gypsum was dehydrated if heated to about 250° C., and from 300° to 400° C. it lost completely the properties of hydration.

Le Chatelier experimented in 1887 on the effects of temperature on gypsum. On heating gypsum to 200° C., he found that there was a constant rise in temperature, with two breaks; the first halt at 128° C. and the second at 163° C., indicating the existence of two different hydrates, whose decomposition took place at the temperatures stated. The dehydration was found to be incomplete at 155° C. and complete at 194° C.

An analysis of the first hydrate gave:

	Per cent.
Water	6.7
Calcium sulphate	93.3
	100.0

This agrees very closely with the formula $(CaSO_4)_2 H_2O$, which gives:

	Per cent.
Water	6.2
Calcium sulphate	93.8
	100.0

Gypsum has 1 part of calcium sulphate united with 2 parts of water, while this hydrate shows 2 parts of calcium sulphate united with 1 part of water. The same hydrate is found in the incrustation of the boilers of ocean steamers when fed with sea water, as shown by the following analysis:

Analysis of boiler incrustation from a trans-Atlantic steamer.

	Per cent.
Calcium carbonate	0.3
Ferric oxide	2.0
Water	5.8
Calcium sulphate	91.9
	100.0

The temperature at which this compound is completely dehydrated lies between 160° and 170° C. Broken up and mixed with water, it hydrates and hardens. Further experiments showed plaster of Paris to be a definite hydrate with the formula $(CaSO_4)_2H_2O$.

The second halt noticed in Le Chatelier's experiments took place at 163° C., and from this temperature to 221° C. no change was noted in the plaster, but beyond 221° C. the plaster, when mixed with water, did not absorb it readily and set only after a long time. If the heat reaches 343° C., the plaster acts like an anhydrite and is said to be "dead burned." It will not set on the addition of water. When heated still more the substance melts and, on cooling, forms a crystalline mass, which can not be decomposed by heat, except in the presence of organic matter, when it changes into CaS. If this substance is acted upon by carbon dioxide gas (CO_2) and water, sulphureted hydrogen gas is formed.

The burning of gypsum is, therefore, a very important matter, and calciners become very expert. If the gypsum is underburned, the new hydrate is not formed, and the plaster will not set. If it is overburned, the plaster sets very slowly.

Lavoisier gave the following account of his theory of set in plaster:

I took the calcined plaster, which hardens readily with water, and threw it into a considerable amount of water. Each molecule of plaster, in passing through the liquid, seized its molecule of water of crystallization and fell to the bottom in the form of small brilliant needles, visible only with a strong lens. These needles, dried in the open air or with the aid of a moderate heat, are very

[1] Chemistry of Agriculture, Vol. I, 1887, pages 206 to 216.

soft and silky to the touch. Under a microscope it is perceived that what was taken under the lens for needles are also parallelopipeds, very fine, some thicker, many thinner, and many more elongated. The plaster in this state is not capable of uniting with water, but if it is calcined anew these small crystals lose their transparency and their water of crystallization and become again a true plaster, as perfect as before. One may, in this fashion, successfully calcine and recrystallize the plaster, even to infinity, and consequently give to it at will the property of seizing water.

Landrin, who, in a paper published in 1874,[1] quoted the above, and gave the results of a study of plaster, divided the set of plaster into four periods as follows:

(1) The calcined plaster, on contact with water, unites with this liquid and takes a crystalline form.

(2) The plaster dissolves partially in the water, which becomes saturated with this salt.

(3) A part of this liquid evaporates, due to the heat set free in the chemical combination. A crystal is formed and determines the crystallization of the entire mass, a phenomenon which is analogous to that which takes place when a piece of sodium sulphate is placed in a saturated solution of this salt.

(4) The maximum hardness is reached when the plaster loses enough water to correspond exactly to the formula $(CaSO_4)_2H_2O$, this maximum being to the remainder in proportion to the quantity of water added to the plaster to transform it into mortar.

The maximum hardness then was reached when the plaster contained about 20 per cent of water. Landrin believed that the loss of water was due to the evaporation.

Le Chatelier showed that plaster would set in a vacuum, so that evaporation was not a necessary step. According to Le Chatelier, the plaster of Paris dissolves, becomes hydrated, and then crystallizes out as gypsum, and every particle of the plaster goes through these steps.

Microscopic examination[2] shows that ground gypsum, before calcination, is composed of rather large masses of various sizes, these masses consisting of more or less broken crystals. After calcination these larger masses are broken up into fine granules nearly uniform in size and shape. As the material is heated, the water is changed into steam and, expanding, breaks the crystals into finer particles. There is thus a physical change, as well as a chemical one.

When water is added to the calcined plaster, small needle-like crystals are seen forming and shooting out here and there, and these, as they become more abundant, unite and form a solid mass, in which the individual crystals can scarcely be distinguished. Open spaces left in the mass are finally closed and a firm solid mass results.

Uncalcined gypsum treated with water shows, under the microscope, very little change. Gypsum crystallized by evaporation shows crystals which are not needle-shaped, but broader and of considerable irregularity. They do not interpenetrate, but form a loose mass which readily crumbles.

Crystallization is aided by the small size of the grains, and the finer-grained plasters set more rapidly than the coarser-grained ones, as shown by the comparison of the fine dental plasters with ordinary plaster of Paris.

Manufacture.—In the manufacture of plaster of Paris the gypsum rock is crushed and ground into flour in a buhr mill, a roller mill, or a disintegrator. The ground gypsum is then passed into storage bins. In some mills the flour gypsum is conveyed to the bins by an air blast.

The calcining kettles are made of boiler steel and hold about 8 tons; the flame is carried around the sides, by flues, so as to heat all parts. In charging, the ground gypsum is run slowly into the kettle, which is kept at a temperature of 212° F. or over; about an hour and a half is consumed in filling to a depth of 5 feet. The material is kept in motion by a mechanical stirrer, it being of the greatest importance that the partly calcined plaster shall not remain in contact with the heated iron. The slow filling tends to keep the heat constant or nearly so during the charging, and as the boiling increases the plaster is occasionally thrown in "waves" out of the kettle. The heated material boils like thick cream, and runs almost like water. The boiling is, of course, due to the escape of the water of crystallization and the hygroscopic water that may be present. The boiling takes about three hours; a short time before completion, when the temperature reaches 270° F., there is a sudden settling down and the steam ceases to rise, marking the period of formation of the first hydrate. Soon the mass begins to boil again; after a certain time, quite accurately determined by the expert calciner, when a temperature of approximately 350° F. is reached, the charge is done, the discharge gate is opened, and the finished product runs out into a vault. The refilling of the kettle for the succeeding charge begins at once.

Retarders.—As plaster of Paris, when mixed with water, sets in from six to ten minutes, material is incorporated therewith, either during its manufacture or at the time of its preparation for use, to delay or hold back the set, in order that the cement plaster can be prepared in quantity and applied with uniform results. These compounds or admixtures are known as retarders or restrainers. In the early days of cement plaster, glue was added by the workman when he prepared the material for use; but now, to secure uniform results, the retarder is, as a rule, incorporated with the plaster in the process of manufacture. Citric acid was used for a time, but this was expensive, and the results were often uneven. As magnesian limes set more slowly than calcareous limes, it was thought that the addition of magnesian limestone would serve as a retarder, but the use of this substance is said not to be a success.

[1] Annales de Chimie, 1874.
[2] University Geological Survey of Kansas, Vol. V, Report on Gypsum and Gypsum Cement Plasters, pages 92 to 95.

In the days of the Romans, blood was used to retard the set of plaster of Paris, and organic matter from slaughterhouse refuse (tankage, bones, hair, etc.), forms the base of many of the retarders now in use.

Any substance which, when added to the water with which calcined gypsum is mixed, or to the dry plaster, will keep the molecules apart or from too close contact will delay the crystallization and retard the setting. Such substances are dirt or organic matter not of a crystalline character. Insoluble material or carbonates of the alkaline earths will dilute the plaster so that it will not set as quickly as the unadulterated plaster. Whether a retarder weakens the cement plaster or not is a disputed question among architects and plasterers, although it is conceded that the addition of too much foreign material reduces the strength of the mass of interlacing crystals. As a general rule the prolongation of the period of crystallization or set is determined by the quantity of retarder added to or incorporated with the plaster. Calcined plaster which sets slowly, whether retarded or not, is known as cement plaster.

Accelerators.—It is a well-known fact that when a salt crystal is dropped into a supersaturated solution of a salt, as for instance sodium sulphate, the whole mass immediately crystallizes. Crystals, or even solid particles of foreign material, will hasten the crystallization. Hence, to make a quick-setting plaster, as for dental use, some other crystallizing salt, as alum or borax, is added, in small quantity, to the calcined gypsum. The result is that, after solution, the added salt has a tendency to crystallize, and thus starts the process in the dehydrated gypsum.

Processes for hardening plaster.—When calcined gypsum is steeped in a solution containing from 8 to 10 per cent of alum, and then dried and again burned with a dull red heat of uniform and constant temperature (Greenwood's process), a plaster is produced which after setting is very much harder than the ordinary plaster. Casts made of such plaster solidify gradually, but finally acquire a hardness similar to that of alabaster or marble, and present a translucent appearance resembling these substances. According to Landrin, this change in the plaster is not to be accounted for by the formation of double sulphates of lime and alkali, nor by the crystals of calcium sulphate being embedded in alumina; but rather by the calcium carbonate in the plaster stone being converted by the alum into calcium sulphate. A liquid containing from 8 to 10 per cent of sulphuric acid acts in a similar manner. Landrin analyzed alum plasters with the following results:

Landrin's analyses of alum plasters.

DESCRIPTION OF SPECIMENS (ALUM PLASTERS).	$CaSO_4$.	CONSTITUENTS.			
		$CaCO_3$.	SiO_2.	H_2O.	Total.
French cement	96.75	1.05	0.72	1.48	100
English cement, No. 1	98.19	0.41	.....	1.40	100
English cement, No. 2	98.02	0.37	0.42	1.19	100
Stucco	98.05	0.36	0.51	1.08	100

These figures show that the alum cements are of great purity and have no trace of alumina or potash.

Keene's hard cement is produced by impregnating plaster of Paris with a solution of 1 part of borax and 1 part of cream of tartar in 18 parts of water, drying and burning at a low red heat for six hours. Borax alone serves the purpose. The plaster hardens more slowly as the solution is more concentrated.

Silicated plaster is formed by sponging the surface of plaster casts with a solution formed by first adding whey, free from fatty matter, to a potash lye solution made by adding 1 part of potash to 5 parts of water, and afterwards mixing 4 parts of this with a simple solution of potassium silicate.

Stearin melted at not too high a temperature has been employed as a bath in which plaster casts are immersed.

Landrin found that lime had great influence on plasters. By mixing lime with the plaster in different proportions, not to exceed 10 per cent, he obtained plaster which set regularly, became very hard, and took a high polish.

A large number of patents have been issued for retarding compounds and admixtures, and for prepared plasters, as well as for processes of manufacture and for hardening gypsum, and a digest of the same will be found in an appendix. There have also been issued some 280 or more patents for improvements in the arts involving the use of gypsum or plaster of Paris in the manufacture of artificial stone, wall and roofing cements, pavements, crayons, blackboards, heat insulating composition, etc.

TABLE 6.—DETAILED SUMMARY: 1902.

	United States.	Iowa.	Kansas.	Michigan.	New York.	Oklahoma.	Wyoming.	All other states.[1]
Number of mines or quarries	62	9	7	6	17	5	3	15
Number of operators	45	3	5	4	15	3	2	13
Character of ownership:								
Individual	13				7		1	5
Firm	6				2			4
Incorporated company	26	3	5	4	6	3	1	4
Salaried officials, clerks, etc.:								
Total number	249	20	19	127	22	12	6	43
Total salaries	$300,420	$15,883	$20,150	$171,245	$32,600	$8,208	$4,228	$48,106
General officers—								
Number	32	2	6	4	6	4	1	9
Salaries	$73,936	$1,625	$10,000	$15,700	$24,400	$2,962	$1,600	$17,649
Superintendents, managers, foremen, surveyors, etc.—								
Number	113	11	6	64	6	6	2	18
Salaries	$153,095	$9,550	$6,110	$108,656	$3,075	$4,700	$1,703	$19,301
Foremen below ground—								
Number	12	3	1	1	4			3
Salaries	$8,948	$2,228	$900	$825	$2,705			$2,290
Clerks—								
Number	92	4	6	58	6	2	3	13
Salaries	$64,441	$2,480	$3,140	$46,064	$2,420	$546	$925	$8,866
Wage-earners:								
Aggregate average number	1,472	293	146	359	214	66	15	379
Aggregate wages	$759,258	$170,828	$71,261	$176,607	$100,996	$34,408	$7,675	$197,483
Above ground—								
Total average number	1,085	149	119	313	141	66	15	282
Total wages	$551,593	$86,020	$58,026	$152,143	$67,408	$34,408	$7,675	$145,913
Engineers, firemen, and other mechanics—								
Average number	101	13	10	28	12	9	1	28
Wages	$63,744	$7,531	$6,254	$17,880	$6,735	$5,878	$532	$18,934
Miners or quarrymen—								
Average number	246	1	12	119	42	16	3	53
Wages	$121,546	$704	$5,973	$55,256	$20,116	$8,309	$1,380	$29,808
Boys under 16 years—								
Average number	3							3
Wages	$500							$500
All other wage-earners—								
Average number	735	135	97	166	87	41	11	198
Wages	$365,803	$77,785	$45,799	$79,007	$40,557	$20,221	$5,763	$96,671
Below ground—								
Total average number	387	144	27	46	73			97
Total wages	$207,665	$84,808	$13,235	$24,464	$33,588			$51,570
Miners—								
Average number	368	133	27	46	73			89
Wages	$198,060	$78,948	$13,235	$24,464	$33,588			$47,825
All other wage-earners—								
Average number	19	11						8
Wages	$9,605	$5,860						$3,745
Average number of wage-earners at specified daily rates of pay:								
Engineers—								
$1.25 to $1.49	1							1
$1.50 to $1.74	3		1		1			1
$1.75 to $1.99	4		1		1	1		1
$2.00 to $2.24	21	6	2	4	5	1		3
$2.25 to $2.49	7	2	3			1		1
$2.50 to $2.74	13		1	6	1	2	1	2
$3.00 to $3.24	1							1
$4.00 to $4.24	2							2
Firemen—								
$1.00 to $1.24	1		1					
$1.50 to $1.74	5			4		1		
$1.75 to $1.99	13	3		4	1			5
$2.00 to $2.24	7	2		1	1	1		2
$2.25 to $2.49	1		1					
$2.50 to $2.74	2					1		1
Machinists, blacksmiths, carpenters, and other mechanics—								
$1.25 to $1.49	1							1
$1.50 to $1.74	1							1
$1.75 to $1.99	3				1			2
$2.00 to $2.24	8			6		1		1
$2.25 to $2.49	4			3	1			
$3.00 to $3.24	1							1
$4.00 to $4.24	1							1
$4.25 and over	1							1
Miners or quarrymen—								
$1.25 to $1.49	25		12		4			9
$1.50 to $1.74	329	23	10	149	90	7	3	47
$1.75 to $1.99	158	52	6	15	18	6		61
$2.00 to $2.24	50	22	11	1	3	3		10
$2.25 to $2.49	21	16						5
$2.50 to $2.74	22	21						1
$3.00 to $3.24	9							9
Boys under 16 years—								
$0.50 to $0.74	3							3
All other wage-earners—								
$0.75 to $0.99	1							1
$1.00 to $1.24	32				1		4	27
$1.25 to $1.49	55		20		3	5		27
$1.50 to $1.74	416	7	57	163	72	29		88
$1.75 to $1.99	161	96	14	3	11			37
$2.00 to $2.24	64	27	6			7	7	17
$2.25 to $2.49	16	16						
$3.00 to $3.24	9							9

[1] Includes operators distributed as follows: California, 1; Colorado, 1; Montana, 2; Nevada, 1; Ohio (2 mines; operator reported in Michigan); Oregon, 1; South Dakota, 2; Texas, 2; Utah, 1; Virginia, 2.

TABLE 6.—DETAILED SUMMARY: 1902—Continued.

	United States.	Iowa.	Kansas.	Michigan.	New York.	Oklahoma.	Wyoming.	All other states.
Average number of wage-earners employed during each month:								
Men 16 years and over—								
January	770	127	109	142	68	24	8	292
February	1,271	251	138	350	194	49	12	277
March	1,304	225	144	350	198	49	16	322
April	1,450	218	153	400	203	49	15	412
May	1,521	231	152	399	221	69	16	433
June	1,608	332	149	401	217	67	15	427
July	1,590	318	145	402	222	67	18	418
August	1,499	323	143	403	230	67	16	317
September	1,693	387	170	402	247	67	16	404
October	1,688	393	155	353	262	92	18	410
November	1,656	374	150	353	254	102	15	408
December	1,583	337	144	353	252	90	15	392
Boys under 16 years—								
January	3							3
February	3							3
March	3							3
April	3							3
May	3							3
June	4							4
July	4							4
August	4							4
September	3							3
October	2							2
November	2							2
December	2							2
Contract work:								
Amount paid	$406							$406
Number of employees	7							7
Miscellaneous expenses:								
Total	$200,769	$6,505	$27,181	$44,715	$14,081	$11,118	$4,452	$92,717
Royalties and rents of mine and mining plant	$49,912	$1,088	$3,507		$7,501	$7,605	$817	$29,394
Rent of offices, taxes, insurance, interest, and other sundries	$150,857	$5,417	$23,674	$44,715	$6,580	$3,513	$3,635	$63,323
Cost of supplies and materials	$341,760	$47,683	$25,626	$88,634	$31,175	$24,097	$15,523	$109,022
Product:								
Gypsum, short tons	816,478	150,323	62,101	240,227	110,364	34,156	9,801	209,506
Gypsum calcined, short tons (before calcination)	674,232	147,723	59,770	158,320	75,230	34,156	9,801	189,232
Marketable product—								
Total quantity, short tons	681,633	120,779	50,147	208,563	95,318	27,325	7,841	171,660
Total value	$2,089,341	$337,734	$205,560	$459,621	$259,170	$111,215	$38,372	$677,669
Crude—								
Quantity	81,455	600		68,885	9,153			2,817
Value	$93,914	$900		$70,460	$15,184			$7,370
Land plaster—								
Quantity	60,791	2,000	2,331	13,022	25,981			17,457
Value	$106,237	$3,000	$3,497	$16,340	$43,750			$39,650
Calcined plaster—								
Quantity	539,387	118,179	47,816	126,656	60,184	27,325	7,841	151,386
Value	$1,889,190	$333,834	$202,063	$372,821	$200,236	$111,215	$38,372	$630,649
Power owned:								
Total horsepower	7,319	1,305	555	1,675	1,469	430	212	1,673
Engines—								
Steam—								
Number	68	14	8	11	13	5	3	14
Horsepower	6,385	1,305	455	1,565	1,225	430	212	1,193
Gas or gasoline—								
Number	2				2			
Horsepower	20				20			
Water wheels—								
Number	11		1	1	6			3
Horsepower	914		100	110	224			480
Electric motors—								
Number	5			1				4
Horsepower	68			25				43

APPENDIX.

DIGEST OF UNITED STATES PATENTS.[1]

GYPSUM AND PLASTER OF PARIS.

I—PROCESSES.

II—RETARDERS.

I—*Processes.*

1361—October 9, 1839. J. D. GREENWOOD and R. W. KEENE. *Cement for forming artificial stone.*

Gypsum is saturated with water in which 1 pound of alum to the gallon has been dissolved and then dried and calcined.

211066—December 17, 1878. C. T. TOMKINS. *Preparing gypsum for use in paper making and other purposes.*

Minutely crystalline sulphate of lime is formed by subjecting gypsum to continuous agitation in a tank with water and to a continuous circulation.

308111—November 18, 1884. J. H. TRICKEY. *Art or process of and composition for making artificial stone.*

It is composed of plaster of Paris, glycerin, and water, and is boiled in a solution of brimstone after becoming set and dried.

309612—December 23, 1884. R. B. EASON and J. J. MCGEVENY. *Cement composition for molding brick, etc.*

A mixture of gypsum and ashes in about equal proportions in a dry pulverized state is boiled in water without agitation until the water is evaporated and the mass dried out.

326047—September 8, 1885. W. MANNING. *Process of treating gypsum.*

Alabaster in the form of a dry precipitated powder is formed by subjecting gypsum to grinding, calcining, and agitation in water, then floating in a floating apparatus, then forcing through a filter, and afterwards drying, crushing, and grinding.

342784—June 1, 1886. U. CUMMINGS. *Manufacture of cement.*

For the manufacture of a hydraulic or Portland cement a mixture of clay 400 pounds and gypsum 1,266 pounds is calcined.

343181—June 8, 1886. E. W. MARSH. *Process of calcining gypsum.*

Ground gypsum in a suitably constructed kettle is exposed to the heat of superheated steam.

395159—December 25, 1888. W. MANNING. *Process of treating gypsum.*

To produce an impalpable opaque anhydrous powder, gypsum is subjected to a second calcination and subsequent reduction by crushing and grinding.

519259—May 1, 1894. H. C. HIGGINSON. *Manufacture of plaster.*

The plaster is heated to about 395°, then cooled to about 365°, and then given a temperature of about 380° and discharged at such temperature.

549151—November 5, 1895. G. W. PARKER. *Process of treating gypsum rock to imitate chalcedony.*

The rock is dehydrated by the action of hot air, and the porous rock is then allowed to absorb a solution of sulphate of iron, nitric acid, and potassium sulphocyanide, after which it is immersed in a solution of aluminum sulphate, $Al_2(SO_4)_3$, for 15 hours, then exposed to the air and polished.

588287—August 17, 1897. G. W. PARKER. *Process of treating gypsum rock to imitate marble.*

The moisture is first removed from the rock by the action of hot air, then the hot rock is placed in a closed compartment charged with the fumes of ammonia, and the cool rock is then immediately immersed in a solution of aluminum sulphate until the pores are filled.

624709—May 9, 1899. F. P. VAN HOOK. *Method of producing plaster products.*

The material is calcined to a pulverulent condition and then, while intensely heated, subjected to the action of a current of cold air of such strength that the particles are taken up and carried in suspension, and rapidly cooled.

655501—August 7, 1900. L. H. MERCERON-VICAT. *Artificial cement.*

Natural marly limestone, or a prepared mixture of calcareous matter and clay, containing sulphur, is calcined and then fused under oxidizing conditions, thereby removing the sulphur while the materials are in a state of fusion.

661247—November 6, 1900. W. R. JOHNSON. *Process of revivifying old plaster of Paris.*

It is subjected to two heatings and an intermediate wetting with acidulated water, the first heating effecting a more complete removal of water than the second, while the intermediate wetting serves to rehydrate the burnt plaster.

674760—May 21, 1901. A. E. CUMMER. *Process of treating hydrous compounds.*

The raw material is heated until dehydration has commenced and has been partially completed, and then the dehydration is completed by the resident heat of the material out of contact with the air.

678412—July 16, 1901. W. LESSING. *Process of burning cement, gypsum, etc.*

The ground raw material is heated to a white heat and dropped downwardly against a column of flame, then cooled, and the resulting heat used for generating steam and for the preliminary warming of the material.

II—*Retarders.*

101253—March 29, 1870. A. H. FREAR. *Manufacture of artificial stone.*

Employs an aqueous saccharine solution of litharge in the manufacture of artificial stone.

165533—July 13, 1875. A. BOAG. *Composition for stone cements.*

Calcined gypsum is saturated with a solution of 1 pound of saltpeter to 4 gallons of water; it is then dried and ground.

225261—March 9, 1880. O. F. WOODWARD. *Composition for making molded articles of manufacture.*

Gypsum and rosin, say in the proportion of 125 pounds of gypsum and 100 pounds of rosin, are mixed together under heat.

[1] Printed copies of patents are sold by the Commissioner of Patents at 5 cents each.

291508—January 8, 1884. H. Graf. *Plastering composition.*

Uses glue and glycerine, together with plaster of Paris, slaked lime, sawdust, and hair.

321620, 321621—July 7, 1885. E. and E. W. Marsh. *Composition of matter to be used as a plaster for building purposes.*

Uses as retarder resin lac dissolved in a solution of caustic soda.

368594—August 23, 1887. G. R. King. *Compound to restrain the setting of plaster.*

The restrainer consists of glue and ground stone.

390157—September 25, 1888. J. Coy. *Composition of matter for plastering, etc.*

The restrainer consists of glue, Irish moss, molasses, and tartaric acid.

391889, 391890—October 30, 1888. J. H. Fitzgerald. *Plastering composition.*

Uses sugar as a restrainer.

392528—November 6, 1888. C. Straub. *Composition of building material for architectural purposes.*

Magnesia is mixed with dissolved glue or gelatinous matter, hydrocarbon compound, acid, and pulverized calcined material, the magnesia producing a smooth and glossy surface.

397296—February 5, 1889. G. R. King. *Compound to restrain the setting of plaster, etc.*

It is composed essentially of animal gelatinous or vegetable glutinous matter and hydrated lime.

409012—August 13, 1889. M. B. Church. *Ornamentation of walls.*

A fatty matter such as oil or glycerine is added as a retarder to alabastine, a mixture of calcined gypsum and glue.

422171—February 25, 1890. G. West. *Composition of matter for architectural purposes.*

A compound of glue and sal soda to be used with plastering material.

422269—February 25, 1890. G. West. *Plastering compound.*

A compound of glue, dextrin, and sal soda to be used with plastering material.

422270—February 25, 1890. G. West. *Composition of matter for architectural purposes.*

It consists essentially of glue or other well-known retarder and boracic acid.

427591—May 13, 1890. R. B. and E. H. Martin. *Wall-covering composition.*

Citric acid is used as a retarder.

433743—August 5, 1890. S. S. Ruston, W. E. Hopkins, and B. Ruston. *Process of manufacturing plastering compounds.*

A dry pulverulent restraining compound is produced by dissolving the restraining substance in water, and mixing therewith a dry, absorbent, comminuted material, by stirring under the application of heat, until it is converted to a dry, pulverulent state.

433899—August 5, 1890. H. Leichsenring. *Artificial plaster.*

It consists of glycolline, plaster of Paris, and water.

437140—September 23, 1890. J. Sickler. *Process of calcining gypsum.*

The retarding agent is incorporated with the plaster during the process of calcining, and while it is in a molten condition and prior to complete calcination.

445211—January 27, 1891. E. Watson. *Composition of matter for retarding the setting of plaster.*

Hair is boiled with an alkali, caustic soda or potash, and used in liquid form, or evaporated and reduced to a powder.

446604—February 17, 1891. E. Watson. *Composition of matter for restraining the setting of plaster compounds.*

A dry leguminous substance, such as peas, beans, lentils, etc., treated with a solution of caustic alkali, mixed with an alkaline earth or a salt of an alkaline earth, or a salt of a caustic alkali, dried and pulverized.

452346—May 12, 1891. I. C. Hart. *Plastering compound.*

Lime is dry slaked with glue water.

456297—July 21, 1891. A. Anthony. *Plastering composition.*

Uses as a retarder in a specified plastering composition a submixture of sugar, slaked lime, and bicarbonate of soda.

458742—September 1, 1891. E. Watson. *Composition of matter for restraining the setting of plaster.*

A mixture of flaxseed or oil meal cake and an alkali, as carbonate of soda or potash, is reduced to a dry powder.

458743—September 1, 1891. E. Watson. *Composition of matter for restraining the setting of plaster.*

Comminuted hoof, horn, or feathers is dissolved by boiling in a solution of caustic alkali, dried, and reduced to a powder.

462678—November 10, 1891. G. W. Abell. *Composition of matter for wall coverings.*

A mixture of white lead, litharge, sugar, linseed (oil cake) meal, lime, calcined gypsum, sand, and water, in specified proportions.

465614—December 22, 1891. G. E. Coy. *Compound to restrain the setting of plaster, and process of making the same.*

A mixture of pulverous quicklime, glue, and flour.

469394—February 23, 1892. G. W. Abell. *Composition of matter for covering walls or other surfaces.*

A mixture of dry oxide of zinc, sugar, flour of sulphur, wood pulp, linseed (oil cake) meal, ground gypsum, lime, sand, and water in specified proportions.

472322—April 5, 1892. E. Watson. *Composition for retarding the solidification of calcined gypsum.*

It consists essentially of calcined gypsum and "tank water;" to retard the setting from half an hour to three hours or more, from 2 to 10 gallons to a ton of calcined gypsum, or of the semisolid substance, stick, from 2 to 10 pounds to the ton, or from 5 to 15 pounds of dry material, formed by mixing any earthy substance, siliceous or aluminous, with tank water and drying and pulverizing.

472511—April 5, 1892. W. Robinson. *Wall plaster.*

A mixture of sand, plaster of Paris, glue, lime, clay, alum, and starch.

478951—July 12, 1892. C. Casstreel. *Plaster.*

A composition consisting of water, lime, gypsum, and coke, or brick dust, with a small proportion of a mixture of sugar, alum, and lime as a retarder.

479060—July 19, 1892. E. W. Dickie. *Composition of matter for plastering.*

A mixture of sand, plaster of Paris, shell marl, and cut rope, or hair, with glue, alum, and sulphate of zinc as a restrainer, combined in a specified manner and proportions.

485177—November 1, 1892. C. L. Denison. *Wall plaster.*

A composition consisting of lime, cottonseed meal, plaster of Paris, borax, and cream of tartar.

493613—March 14, 1893. E. A. Bronson. *Compound for retarding the setting of cement.*

It is composed of air-slaked lime, glue, flaxseed, or oil cake, and china clay, in specified proportions.

502096, 502097—July 25, 1893. T. J. Heller. *Plaster composition.*

A compound for admixture with a plaster composition consisting of silicate and carbonate of soda, alum, sugar, gum, salt cake, and ground inert material.

503592—August 22, 1893. J. Flynn. *Composition for architectural purposes.*

The retarder, combined with other ingredients, consists of a solution of carbonate of potash and glue absorbed in quicklime.

504933—September 12, 1893. E. A. Moore. *Composition for architectural purposes.*

A mixture of dry pulverous glue, sulphuric acid, kerosene oil, and quicklime, as a retarder, is combined with sand, raw gypsum, and lime.

507942—October 31, 1893. B. D. STAFFORD. *Composition for plaster and coating walls.*

It consists of powdered borax, powdered alum, wheat flour, powdered sugar, and dry slaked lime in specified proportions.

511735—December 26, 1893. J. K. JONES. *Wall plaster.*

The retarder is composed of sugar, 100 parts; flour, 25 parts; and air-slaked lime, 250 parts.

511740—December 26, 1893. J. R. MCILVRIED. *Process of manufacturing retarders for plaster.*

A paste is formed of air-slaked lime, water, flour, liquid glue, and wood ashes, dried and thoroughly mixed.

511879—January 2, 1894. W. M. DAWSON. *Plastic compound and process of making same.*

The restrainer consists of a mixture of lime with the liquor obtained by the decomposition of organic matter in water.

523658—July 31, 1894. W. M. DAWSON. *Plastering retarder and method of making same.*

The restrainer consists of a mixture of lime, sodium nitrate, and the liquor obtained by the decomposition of organic matter in water.

528995—November 13, 1894. A. W. SMITH. *Plastering compound.*

The restrainer consists of lime, glue, wheat flour, and tartaric acid in certain proportions.

533420—February 5, 1895. W. H. AIKMAN. *Building plaster.*

As an ingredient of building plaster, a compound of alum, wheat flour, sugar, lime, oil cake meal, and zinc sulphate in specified proportions.

554142—February 4, 1896. W. M. REESE. *Plaster.*

A mixture of pulverized gypsum and dry tankage in the proportions of 10 pounds of tankage to a ton of gypsum, is calcined and the heat continued to a temperature of 380° to 420° F.

558435—April 14, 1896. J. E. SUMMERS. *Plastering compound.*

A mixture of furnace slag, slaked lime, plaster of Paris, hydraulic cement, the flour of grain, and vegetable fiber in specified proportions.

619911—February 21, 1899. H. E. STURCKE. *Manufacture of plaster and restrainers.*

The restrainer consists essentially of the pulverized residue of an evaporated solution of bone in alkali.

PHOSPHATE ROCK

PHOSPHATE ROCK.

By Joseph Struthers, Ph. D.

Prior to the report of 1880 no figures relating to the production of phosphate rock appeared in census reports. In that year 21 establishments were reported in South Carolina, with a product of 211,377 tons, valued at $1,123,823. At the Eleventh Census the production for 1889 was shown, and the totals, compared with those for 1902, appear in Table 1.

Table 1.—*Comparative summary: 1902 and 1889.*

	1902	1889
Number of mines or quarries	115	(1)
Number of operators	87	(1)
Salaried officials, clerks, etc.:		
Number	391	(2)
Salaries	$355,204	(2)
Wage-earners:		
Average number	5,971	[3] 5,011
Wages	$1,930,093	[4] $1,209,151
Contract work	$157,402	$115,930
Miscellaneous expenses	$430,475	$343,271
Cost of supplies and materials	$799,414	$317,159
Product:[5]		
Quantity, long tons	1,548,720	550,245
Value	$4,922,943	$2,937,776

[1] Not reported.
[2] Not reported separately.
[3] Includes foremen.
[4] Includes salaries of office force.
[5] The United States Geological Survey reports 1,490,314 short tons, valued at $4,693,444, which is the product marketed. The Census figures represent the product mined.

The most notable fact in the industry is the transfer of dominance from South Carolina to Florida. During the period between 1889 and 1902 the production in Florida increased nearly one hundredfold in quantity and over sixtyfold in value; at the same time that of South Carolina decreased 39.5 per cent in quantity and 67.1 per cent in value. The increase in Florida was due chiefly to the exportation of phosphate rock which is easily mined near tide water. Tennessee did not produce any rock in 1889, but in 1902 the production of the state was 432,603 long tons, valued at $1,308,872. This rock, however, was of low grade, averaging in value only $3.03 per ton. North Carolina did not report any product in 1902 and in 1889 its production reached a total valuation of only $5,000. By the growth of the industry in Florida and in Tennessee the production for the United States as a whole increased 181.5 per cent in quantity and 67.6 per cent in value.

Among the most significant items of Table 1 are those relating to wage-earners and their earnings. By this table it appears that the number of salaried officials, clerks, etc., and wage-earners increased 1,351, or 27 per cent, while the amount paid in salaries and wages increased 89 per cent. The number of boys employed was not large in either year, and although the industry increased in all other respects, the number of boys decreased from 91 to 37, or 59.3 per cent. In South Carolina, where 90 boys were employed in 1889, none were reported in 1902. The figures in Florida in 1889, however, do not offer a wholly satisfactory basis upon which to make comparisons. Mining operations had been recently begun, and the industry was in a condition of speculative excitement.

There were 19 mines in Florida, South Carolina, and Tennessee reported idle during 1902, and 2—1 each in Florida and North Carolina—at which development work was reported. The statistics for the development work at these 2 mines are shown in the following statement:

Development work: 1902.

Number of mines	2
Number of operators	2
Salaried officials, clerks, etc.:	
Number	4
Salaries	$4,315
Wage-earners:	
Average number	5
Wages	$1,323
Miscellaneous expenses	$666
Cost of supplies and materials	$726

Capital stock of incorporated companies.—The details of the capitalization of the 56 incorporated companies are shown by states in Table 2:

TABLE 2.—*Capitalization of incorporated companies: 1902.*

	United States.	Florida.	South Carolina.	Tennessee.	All other states.[1]
Number of incorporated companies	56	24	9	21	2
Number reporting capitalization	53	21	9	21	2
Capital stock and bonds issued	$13,775,935	$5,982,800	$1,634,500	$5,957,200	$201,435
Capital stock:					
Total authorized—					
Number of shares	204,955	98,755	21,150	63,550	21,500
Par value	$13,269,500	$5,003,000	$1,995,000	$6,070,000	$201,500
Total issued—					
Number of shares	194,796	97,734	16,465	59,162	21,435
Par value	$12,321,135	$4,962,000	$1,526,500	$5,631,200	$201,435
Dividends paid	$316,205	$104,380	.....	$211,825	.....
Common—					
Authorized—					
Number of shares	184,955	96,655	21,000	45,800	21,500
Par value	$11,292,000	$4,793,000	$1,980,000	$4,317,500	$201,500
Issued—					
Number of shares	174,796	95,634	16,315	41,412	21,435
Par value	$10,343,635	$4,752,000	$1,511,500	$3,878,700	$201,435
Dividends paid	$179,115	$72,490	.....	$106,625	.....
Preferred—					
Authorized—					
Number of shares	20,000	2,100	150	17,750	.....
Par value	$1,977,500	$210,000	$15,000	$1,752,500	.....
Issued—					
Number of shares	20,000	2,100	150	17,750	.....
Par value	$1,977,500	$210,000	$15,000	$1,752,500	.....
Dividends paid	$137,090	$31,890	.....	$105,200	.....
Bonds:					
Authorized—					
Number	4,530	3,986	108	436	.....
Par value	$1,735,800	$1,276,800	$108,000	$351,000	.....
Issued—					
Number	3,518	3,024	108	386	.....
Par value	$1,454,800	$1,020,800	$108,000	$326,000	.....
Interest paid	$61,750	$55,510	$3,240	$3,000	.....

[1] Includes companies distributed as follows: Arkansas, 1; Ohio, 1.

The total amount of common and preferred stock issued amounted to $12,321,135. On this amount $316,205 was paid in dividends, or 2.6 per cent on the total par value. On the bonded indebtedness $61,750 was paid as interest. This was 4.3 per cent of the par value of the amount issued. In Tennessee the dividends on common stock amounted to 2.7 per cent, and those on preferred stock to 6 per cent on the respective par values of the stock issued. In Florida, with a capitalization quite similar in amount, dividends were paid on common stock at the rate of 1.5 per cent, and on preferred stock at the rate of 15.2 per cent.

Employees and wages.—The average number of wage-earners reported for each month in Table 6 shows that the demand for labor was relatively steady throughout the year. In the South the climate is favorable to the continuous working of deposits. Between September, for which month 6,442 wage-earners, the maximum number, were reported, and February, when 5,366 wage-earners, the minimum, were at work, there is a variation of only 1,076. The average per month for the year was 5,971 wage-earners. Child labor constituted six-tenths of 1 per cent of the total, and was confined mostly to the small colored boys who drove carts. Florida employed 48 per cent of the total number of wage-earners; South Carolina, 25.1 per cent; Tennessee, 26.7 per cent; and all other states, two-tenths of 1 per cent.

A segregation of the occupations in this industry by specified daily rates of pay is shown in Table 3.

TABLE 3.—*Average number of wage-earners by specified daily rates of pay: 1902.*

RATE PER DAY (DOLLARS).	All occupations.	Engineers.	Firemen.	Machinists, blacksmiths, carpenters, and other mechanics.	Miners or quarrymen.	Timbermen and track layers.	Boys under 16 years.	All other wage-earners.
Total	5,971	173	169	171	4,382	111	37	928
Less than 0.50	52	.....	.....	.....	.....	.....	7	45
0.50 to 0.74	89	.....	.....	1	6	.....	27	55
0.75 to 0.99	1,288	.....	14	20	1,010	10	2	232
1.00 to 1.24	3,656	5	76	8	2,990	100	1	476
1.25 to 1.49	378	5	37	28	226	.....	.....	82
1.50 to 1.74	250	52	27	25	126	.....	.....	20
1.75 to 1.99	25	3	8	4	1	1	.....	13
2.00 to 2.24	101	47	7	35	7	.....	.....	5
2.25 to 2.49	33	24	1	7	1	.....	.....	.....
2.50 to 2.74	55	20	4	29	2	.....	.....	.....
2.75 to 2.99	3	1	.....	.....	2	.....	.....	.....
3.00 to 3.24	21	11	.....	6	4	.....	.....	.....
3.50 to 3.74	4	2	.....	1	1	.....	.....	.....
3.75 to 3.99	3	.....	.....	1	2	.....	.....	.....
4.00 to 4.24	5	2	.....	1	2	.....	.....	.....
4.25 and over	8	1	.....	5	2	.....	.....	.....

Of the wage-earners, 1,429, or 23.9 per cent of the whole, received less than $1 per diem, and 5,085, or 85.2 per cent, less than $1.25. Only 233, or 3.9 per cent, received $2 or more per diem. Of the wage-earners in Florida 5.9 per cent received $1.75 or more per diem, while in South Carolina the corresponding percentage was 3.9. In Tennessee only 1.9 per cent received $1.75 or more.

Mechanical power.—The primary power reported for this industry aggregated 14,229 horsepower, all owned by the operators reporting, distributed as follows: 282 steam engines with a horsepower of 13,974, 1 water wheel of 170 horsepower, and 2 air compressors of 85 horsepower. There were also 9 electric motors with 500 horsepower.

Production.—The quantity and value of the production of phosphate rock, beginning with 1889, are shown in Table 4.

TABLE 4.—*Production of phosphate rock: 1889 to 1902.*

[United States Geological Survey, "Mineral Resources of the United States," 1902.]

YEAR.	Quantity (long tons).	Value.
1889	550,245	$2,937,776
1890	510,499	3,213,795
1891	587,988	3,651,150
1892	681,571	3,296,227
1893	941,368	4,136,070
1894	996,949	3,479,547
1895	1,038,551	3,606,094
1896	930,779	2,803,372
1897	1,039,345	2,673,202
1898	1,308,885	3,453,460
1899	1,515,702	5,084,076
1900	1,491,216	5,359,248
1901	1,483,723	5,316,403
1902	1,490,314	4,693,444

During this period the quantity of production has increased 170.8 per cent. The greatest amount produced in any one year was 1,515,702 long tons in 1899. In 1889 the average value per ton was $5.34, while in 1902 it was $3.15. The production of phosphate rock in the world, from 1896 to 1901, is given in Table 5.

TABLE 5.—WORLD'S PRODUCTION OF PHOSPHATE ROCK: 1896 TO 1901.

[United States Geological Survey, "Mineral Resources of the United States," 1902.]

[Metric tons.]

COUNTRY.	1896		1897		1898		1899		1900		1901	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Algeria	165,738	$500,905	228,141	$912,564	269,500	$1,078,000	324,983	$1,299,932	319,422	$1,277,688	265,000	$1,060,000
Belgium	[1] 297,470	537,320	[1] 350,056	436,762	[1] 156,920	303,230	[1] 190,090	342,180	[1] 215,670	367,164	222,520	361,398
Canada	517	3,420	824	3,981	665	3,665	2,722	18,000	1,284	7,105	937	6,280
France	582,667	3,502,027	535,390	2,852,887	568,558	3,115,958	645,868	3,334,145	587,919	2,827,291	535,676	2,614,543
Norway	1,106	17,280	872	12,960	3,593	53,352	1,500	22,140	300	4,445	(2)	.....
Redonda (British West Indies)	.....	.....	812	5,525	750	4,725	1,507	9,270	2,230	13,720	Nil.	.....
Russia	3,776	11,065	5,917	22,132	1,870	4,784	16,863	58,640	25,663	(3)	(2)	.....
Spain	770	3,080	2,084	16,672	4,500	46,003	3,510	35,100	4,170	18,590	4,220	16,880
United Kingdom	3,048	26,250	2,032	17,500	1,575	13,565	1,469	12,645	630	5,425	71	680
United States	945,982	2,803,372	1,056,322	2,673,202	1,330,264	3,453,460	1,540,506	5,084,076	1,515,179	5,359,248	1,507,681	5,316,403

[1] Cubic meters. [2] Statistics not yet available. [3] Value not reported.

The detailed statistics of the industry for 1902 are given in Table 6.

DESCRIPTIVE.

The name phosphate is applied to the salts of phosphoric acid, chiefly "orthophosphoric" acid, which is a tribasic acid (H_3PO_4) and from which a great variety of salts are obtained. Each of the three hydrogen atoms in the acid can be replaced by a monad element, forming, consequently, three varieties of salts, namely, those in which one hydrogen atom is replaced, those in which two hydrogen atoms are replaced, and those in which all of the hydrogen atoms are replaced. Salts in which all of the hydrogen atoms have been replaced are called ortho or neutral phosphates, while those still containing one or two atoms of hydrogen are called acid phosphates. Calcium phosphate, or, more strictly speaking, tricalcium orthophosphate, is the most important of the mineral phosphates and this class forms the large mineral deposits utilized for the manufacture of fertilizers.

Historical.—According to historical records, the Romans utilized the excrement of birds for fertilizing the soil, and in the twelfth century the Arabs and Peruvians used the guanos of their respective countries for a like purpose.

The waste clippings of bone and ivory from the button and knife factories of Sheffield, England, greensand from the counties of Kent and Essex, England, marls from the state of New Jersey, and boneblack (spent animal charcoal) and crushed bones were used as fertilizers at different times during the eighteenth and nineteenth centuries, but while the beneficial results from their use were recognized and appreciated, the real cause of the stimulating effect seems not to have been definitely recognized until Dr. Justus von Liebig, of Geissen, Germany, evolved the idea that sulphuric acid should be added to bone fertilizers in order to render soluble the phosphate they contained. It was not until the year 1843 that the Duke of Richmond, after an exhaustive series of experiments upon the soil with both fresh and degelatinized bones, came to the conclusion that their value for fertilizing purposes was due to the large quantity of phosphoric acid contained in them. To prove this effect a number of vegetables were planted in burnt sand rich in every element of fertility except phosphoric acid; no development of the plant took place until calcium phosphate had been added to the sand, but after this addition the growth became flourishing.[1]

The calcium phosphate in bones had hitherto been considered as useless owing to its insolubility, and the fertilizing element was considered to be the gelatinous matter. Shortly after 1840 Mr. J. B. Lawes put Doctor von Liebig's ideas into practice, and began to manufacture artificial fertilizers at Deptford (London), England, by mixing sulphuric acid with crushed bones. In the year 1845 Professor Henslow recommended that the Cambridge coprolites, rich in calcium phosphate, should be used as a substitute for bones in making fertilizers, and, acting on this suggestion, the numerous bone crushing works were quickly converted into chemical fertilizer and superphosphate factories. The coprolites of Cambridge were supplemented by the phosphate deposits in Suffolk and Bedfordshire, but it was not until twenty-five years later that the phosphate mining industry began to assume a commercial importance. This slow growth is attributed to the immense supply of guano obtained from Peru, the best beds of which did not become exhausted until between 1870 and 1875; the failure of this source of supply immediately led to the substitution of other material for the manufacture of fertilizers.

Occurrence.—In France the phosphate deposits at

[1] Phosphates of America, by Francis Wyatt, Ph. D., page 19.

Estimated mean annual quantity and value of certain vegetable products in the United States.

	Average percentage of ash or mineral.	Quantity (bushels).	Value.
Wheat	2.06	450,000,000	$440,000,000
Maize	1.55	1,900,000,000	627,000,000
Oats	3.18	600,000,000	168,000,000
Potatoes	3.77	200,000,000	100,000,000
Hay	7.24	[1]45,000,000	360,000,000
Cotton	3.10	[2]6,500,000	250,000,000

[1] Tons. [2] Bales (480 pounds).

According to Wyatt, the total weight of the ash contained in the entire annual cereal production of the United States (wheat, maize, oats, barley, rye, and buckwheat), about the year 1890, exceeded 17,500,000,000 pounds, containing 2,714,585,473 pounds of phosphoric acid.[1] Of course, a large part of the phosphate content of the plants was returned to the soil in one form or another, but the annual loss to the soil was nearly 1,500,000 pounds of phosphoric acid.

As the area of cereal production at that time was 140,378,857 acres, these figures show that the quantity of phosphoric acid removed annually by the cereal crop is approximately 19 pounds per acre. Similarly, the quantity removed by the hay crop is calculated to be 12.5 pounds per acre. Further, it has been shown that every cow kept on pasture land carries off during a summer not less than 50 pounds of calcium phosphate in the shape of veal, butter, and cheese.[2]

These few instances show in a striking manner the enormous loss of phosphoric acid occurring in agricultural districts, and the necessity of returning to the soil those salts which have been removed therefrom.

REVIEW OF THE INDUSTRY IN THE UNITED STATES.

The phosphate deposits of the United States are described by states as follows:

Florida.—Phosphate rock occurs over a large area, extending from Lake Okeechobee on the south to the extreme northern part of the state—a distance of 240 miles, and averaging 30 miles in width. The deposits of commercial value, however, are comparatively few in number and are widely scattered throughout the region. The three chief classes of the phosphate rock product in the order of importance are hard rock, land pebble, and river pebble.

Hard rock is mined in an area of 90 by 10 miles, extending from Albion on the north to Bay City on the south. The material is obtained from pockets which vary in yield from a few tons to many thousands, and run so irregularly that it is frequently necessary to change the location of the mining plants. In former times the mining operations were limited solely to the bowlders of phosphate rock, which varied in weight from a few pounds to many tons. The mining consisted in removing the rock from the pits, drying it in the kilns, and shipping it without any additional preparation. Little capital was called for, and many hard-rock companies were formed to mine the rock, but they finally withdrew from business on account of the scarcity of deposits easy of extraction. Attention was then directed to mining the gravel phosphate, which represents the smaller or broken pieces of the bowlders that occur intermixed with clay, flint, etc., the sterile material being removed by washing in the ordinary log washer. Later, as the mining and milling processes became more complicated and costly, large central plants were erected for cheaper treatment cost, but the economies sought, however, were not realized, on account of the small size of the individual deposits and the consequent expense of transporting the crude material containing less than 15 per cent tricalcic phosphate from the mines to the mill.

At the present time the cheapest method of treatment is to have one or more removable washing plants, each of a capacity of from 40 to 50 tons of clean rock in twelve hours. These plants are so constructed that they can easily be taken down and removed to new localities. It is also the present practice to crush, wash, and screen the entire product of the mine.

The most recent practice in mining hard rock is the installation of dredges of the dipper type to mine deposits that have been worked down to the water level, particularly in those cases where it has been found impracticable to handle the water with pumps. The use of the dipper dredge is economical, and with deposits that can be handled by this method very excellent results have been obtained, so much so that deposits unworkable at a profit by the older methods of mining are now treated with commercial success, the clay, sand, and fine material being removed in log washers plentifully supplied with water. The washed rock is carefully hand picked on a picker belt, dried in kilns, which consume from 5 to 7 cords of wood per 100 tons of rock, and is then ready for shipment to market.

The average cost of production, f. o. b. at the mines during 1900 was from $3.50 to $4 per ton. According to C. G. Memminger those deposits most favorable for cheap transportation and mining are almost exhausted, and the present efficient methods of mining and handling leave but little room for diminishing the cost, consequently with the gradual exhaustion of the best

[1] Phosphates of America, page 15.
[2] United States Geological Survey, Bulletin 46, "Nature and Origin of Deposits of Phosphate of Lime," by R. A. F. Penrose, Jr.

Grand Pré, in the Ardennes, began to be exploited in 1856, and small quantities of the rock in a ground state were utilized by direct addition to the soil. In 1865 other deposits were discovered on the plateau of Querey, in the department of Lot, and in 1870 the deposits of Lot-et-Garonne, Tarn-et-Garonne, and Aveyron (known as the Bordeaux phosphates) were mined and the product sold to fertilizer manufacturers. In Spain the mining of phosphate rock began at Logrosan, province of Estremadura, about the year 1855, followed, in 1860, by the exploitation of the deposits near Caceres, the latter district yielding a considerable quantity annually until 1875. In Norway phosphate deposits were mined at Kragerö, in 1854, and at Oedegarten, in 1874. In Germany the Nassau phosphate deposits were discovered in 1864 and the mining of the rock commenced at once. In recent years the competition in the world's markets of higher grade and purer phosphates from other countries has caused the cessation of the exports of rock from the Lahn mines, the material of which contains a large percentage of iron and aluminum oxides. In a few of the islands of the West Indies, notably Navassa and Sombrero, prior to 1865 phosphate deposits had been opened and the product shipped to the United States and the United Kingdom.

In the United States deposits were first worked in South Carolina in 1867. From 1867 to 1877 there was a great advance in the world's production of phosphate rock. In 1873 Belgium began contributing to the world's supply from the deposits near Mons, and France increased its production very largely. In 1880 the islands of Curaçao and Oruba, in the Dutch West Indies, supplemented the output of high-grade phosphates and shipped an average of 10,000 tons for the year.

In the decade 1880 to 1890 the sources of the supply of phosphate rock altered very considerably. At the end of this period Spain, which in 1882 and 1883 shipped 100,000 tons to the United Kingdom, practically ceased to export. In France the old sources of supply had been replaced to a large extent by the newer fields in the Somme and other departments in the north. Belgium had assumed an important place, producing about 150,000 tons of phosphate from the mines at Mons alone. In the United States the South Carolina deposits had been developed to a very large extent and Florida had begun to contribute appreciably to the supply.

Characteristics and use.—The various deposits of phosphatic material have not yet been classified geologically owing to the difficulty in determining the position of several of the deposits, augmented by the large number of forms which the phosphate assumes and the complex blending of certain varieties. The common technical classification makes the broad distinction between mineral phosphates, whose origin can not be traced to animal life, and rock phosphates, more or less mineralized, but directly traceable to an organic origin. On this basis the only mineral phosphates are those containing crystalline apatite, which occur in Canada, Norway, and a few localities in Spain. The deposits at Nassau in Germany, Lot-et-Garonne, Tarn-et-Garonne, and Aveyron in France, and Logrosan and Caceres in Spain are usually included in the mineral phosphates under the arbitrary and indefinite term "phosphates." The term rock phosphates includes the remaining varieties of phosphatic limestone, coprolites, nodular phosphates, concretionary phosphates, arenaceous phosphates, sheet-rock phosphates, and bone beds.

The value of phosphate rock in the United States lies solely in its use as a fertilizer to enrich land impoverished by continual removal of crops that have grown thereon, or land which did not originally possess the components necessary for the normal growth and development of plant life.

It has been only within comparatively recent years that the relation between plants and soils has been scientifically studied. In general the manner of life in plants resembles that of animals or man, in that they require certain foods in stated proportions which are digested or assimilated, they must breathe a certain atmosphere, and they are subject to the influence of heat and cold, light and darkness. The tissues of plants, like those of animals, are composed of carbon, hydrogen, oxygen, nitrogen, and certain mineral acids or bases, notably phosphoric and sulphuric acids, lime, magnesia, iron, and potash; and the growth of a plant bears a close relation to that of an animal for the reason that it constantly absorbs elements from the soil and air to build up its structure. The relation of plant life to animal life is reciprocal. Animals breathe in the oxygen of the air and convert a small part of it into carbon dioxide, which is exhaled and returned to the air, while plants, under the action of chlorophyl and sunlight, absorb carbon dioxide from the air and decompose it into carbon and oxygen, utilizing the former to build up the cellular structure and returning the oxygen to the air. The chief elements assimilated by plants, and consequently removed from the soil when the plants are cut down and taken away, are nitrogen, phosphoric acid, and potash. These compounds play a very important part in the functions of vegetation and are the most liable to be exhausted from the soil. The estimated mean annual quantity and value of a few of the important vegetable products in the United States have been compiled as follows:[1]

[1] Phosphates of America, page 14.

and greatest yield per acre are fast being exhausted, and fuel, which is a large item of cost, is rapidly being exhausted in the vicinity of the mines. The question of fuel supply is one of great importance in connection with the future of the industry. Large tracts of woodland have been bought up by the various companies, but wood will undoubtedly be supplemented by coal when the mines control the transportation to the point of shipment. Fuel oil also will become a possible substitute for wood under the new conditions of transportation.

The present cost of production, f. o. b. at the mines, is from $1.50 to $2 per ton, a figure that will doubtless increase very materially in the near future. The product is shipped from Port Tampa. At the present rate of production the deposits containing 68 per cent and upward of tricalcic phosphate, and low in iron and aluminum oxides, will be exhausted within a few years. Those containing from 64 to 67 per cent tricalcic phosphate and from 4 to 6 per cent iron and aluminum oxides are in very large reserves. There has been a marked tendency toward more careful methods in the preparation of the rock for the market, which is attained usually by installing one or more log washers in addition to the ordinary double log washer plant; and by crushing the rock after it has been dried, and subsequently screening it, this procedure has been productive of good results with certain classes of rock.

As the higher grade deposits become exhausted the methods of treatment must be improved in order to handle the lower grade rock at a lessened cost. As a proof of the growing scarcity of the best class of rock, deposits having an overburden of from 25 to 30 feet are now being opened up and developed. Deposits of this character a short time ago were declared unsuited for profitable working.

The excessively high transportation and terminal charges prevailing in recent years have forced miners to seek relief. One company has constructed a private railroad from the central plant at Rockwell to Port Inglis, 18 miles distant, at the mouth of the Withlacoochee river. The port is an open roadstead, and the vessels have to be loaded by lighters.

As in the case of the hard-rock miners, there have been several unsuccessful efforts to consolidate the large miners of land pebble into a community of interests, which would eliminate useless competition and enable the producers to maintain prices at a level which would admit of mining at a fair profit.

The bulk of the river pebble has been obtained from Peace river, which rises near Bartow and flows 200 miles in a southerly direction into Charlotte harbor. The Alafia river, a small stream flowing into Tampa bay, has also contributed a small quantity of river pebble, and the Caloosahatchee, Miakka, and Manatee rivers have produced a pebble of low grade.

The method of mining the river pebble consists in using dredging boats equipped with 8-inch or 10-inch centrifugal pumps, to which are attached suction pipes suspended from cranes. The pebble, being loosely mixed with sand, is readily raised by the pumps and passed into a rotary screen, which separates the sand and delivers the washed pebble onto a lighter moored alongside the dredge. When a sufficient quantity of pebble has accumulated on the lighter, it is carried to the drying plant, dried in rotary calciners, and stored in bins, from which it is finally discharged by gravity directly into cars for shipment. As the supply of pebble in the river beds became exhausted, attention was given to the deposits lying under the swamps which were formed by the river at an earlier period. Generally these deposits are covered with an overburden of sand of from 5 to 15 feet in thickness, supporting a thick growth of heavy timber. In order to obtain the river pebble from the swamp deposits the timber was removed and the overburden washed into the stream and removed by pumps; later the pebble was obtained in like manner and treated similar to the pebble in the river beds.

The total production of phosphate rock of all classes in Florida, as reported by the United States Geological Survey, based on marketed output from 1888, the year of the inception of the industry, to and including 1902, aggregates 6,606,468 long tons, valued at $24,667,099.

South Carolina.—Although the phosphate deposits in South Carolina had been known for many years, they were not recognized as such prior to the Civil War. A mining company was formed in 1867 to test the practicability of working the phosphate rock on a commercial scale. The phosphate "belt" is composed of Quaternary sands and clays overlying beds of Eocene marls upon whose surface, and intermixed with it, are found the phosphate deposits. The presumed total area of the phosphate formation is 70 by 30 miles, extending from the mouth of the Broad river, near Port Royal on the southeast, to the headwaters of the Wando river in the northeast, its major axis being parallel to the coast line and its greatest width near Charleston. The stratum of phosphate rock sometimes outcrops at the surface, but it is generally found at a depth of from 3 to 20 feet and varies in thickness from a few inches up to 3 feet. The chief points for consideration in order to ascertain the value of the phosphate beds are thickness of deposit, depth below the surface, and richness in phosphoric acid.

In South Carolina the general method of ascertaining the value of a phosphate rock deposit is by means of boring and pit sinking. At first a careful topographical survey of the property is made, followed by the systematic sinking of a series of bore holes by means of a long steel borer or rod specially designed for the purpose. The boring rod is forced downward through the upper strata until it strikes the solid bed of phosphate rock, which makes itself evident by resisting the further passage of the rod. The rod is then removed, and the distance it has traversed is measured with a

deposits the cost of production must increase. It is quite probable that the cost of production of from $3.50 to $4, f. o. b. at the mines, is as low as it ever will be. The cost to the consumer, however, is regulated largely by the cost of transportation from mines to port of shipment.

Hard rock is sold on a guarantee of a minimum of 77 per cent tricalcic phosphate (bone phosphate of lime) and a maximum of 3 per cent iron and aluminum oxides. Practically the entire output is exported, chiefly to Germany. The ports for shipment of hard rock are Fernandina, Port Inglis, and Tampa, Fla., and Brunswick and Savannah, Georgia.

The land pebble phosphate rock occurs in Polk, De Soto, and Hillsboro counties, Florida, occupying an area of about 2,000 square miles, beginning a few miles north of Bartow and extending over the upper portion of the drainage basin of the Peace and Alafia rivers. During the past few years the entire product has been obtained from Polk county. The area of the occurrence of land pebble is restricted and the deposits widely scattered, rendering this branch of the industry of comparatively less importance than the others, yet several hundred thousand tons of phosphate may be obtained from a single deposit. The pebbles are roughly rounded, of a gray or brownish color, and vary in size up to two inches in diameter. In preparing the material for the market two classes of product are made, the size of the coarser being from one-sixteenth to 1 inch in diameter. The deposits are usually along the stream courses, in low swamps, or in bay heads. The thickness of the deposits varies from a few inches to 18 feet, averaging 10 feet for the district. The pebble, which usually represents less than 25 per cent of the mass, occurs in an argillaceous matrix, sometimes very sticky and tenacious, and sometimes sandy and readily disintegrated; the overburden consists of sandy soil, clay, and a so-called conglomerate rock of varying character in different parts of the deposit. The bed rock varies from a hard yellow marl to a soft, clay-like material. The highest grade of land pebble contains from 68 to 73 per cent of tricalcic phosphate and from 3 to 4 per cent of iron and aluminum oxides; the low-grade material has from 60 to 65 per cent of tricalcic phosphate and from 4 to 5 per cent of iron and aluminum oxides. At the present time land pebble is sold on a guarantee of a minimum of 68 per cent of tricalcic phosphate and a maximum of 4 per cent of iron and aluminum oxides; conditions which, in order to operate at a profit, call for an average yield of 20 per cent of pebble to the mass, an average minimum thickness of 8 feet of the deposit (yielding 3,733 tons to the acre), and an overburden not exceeding the thickness of the deposit.

Within recent years a hydraulic method of treating land pebble has been devised, which is undoubtedly the only practical method of handling this class of material. The important feature of the process is that the water which is used to break down the rock also partially disintegrates the matrix and renders the succeeding washing for the separation of the pebble a very simple operation. According to C. G. Memminger the equipment of a hydraulic plant consists of a steam shovel for removing the overburden, one or more dredges fitted with boilers of from 400 to 500 horsepower, a 10-inch centrifugal pump, hydraulic-pressure pumps, screens and washers, and barges to carry the pebble to the mill. The mill should contain a sufficient number of washers, rotary driers, elevators, boilers, and dry-storage bins of from 4,000 to 15,000 tons capacity—an equipment which calls for a heavy investment. A plant with one dredge and two driers should produce 50,000 tons of pebble per year. The method of mining is briefly outlined as follows: The overburden having been removed by the steam shovel, the dredge is launched in a suitable excavation and the suction pipe from the centrifugal pump on the dredge is laid some 150 feet in advance, where a small sump hole is opened for suction. Streams of water from two hydraulic giants, working under a pressure of from 100 to 110 pounds per square inch, are directed into the hole, which is increased to a considerable size in a short time. The suction gradually becomes lowered until the sump is formed in the bed rock. As soon as possible the giants are placed in the pit, and as the banks are cut down the material passes with the water to the sump and is pumped to the dredge, where it is screened, the pebble being thoroughly washed and separated and the débris discharged at the side of the dredge. As the pit becomes enlarged it is a good practice to use a second centrifugal pump in connection with the pump on the dredge. In this way a pit of several acres in extent can be mined. The pump and pipes are removed from the pit as soon as economy in pit size is reached. The pit is filled with water and the bank between the dredge and the pit is broken. The dredge is then moved on and operations begin afresh. The pits form a channel for the transportation of the pebble in barges. On reaching the mill the pebble is elevated, thoroughly washed, dried, and stored for shipment.

The most modern plant in this district has been equipped with electric motive power, the intention being to eliminate the dredge by using a series of electrically-driven centrifugal pumps which will force the entire material mined to the mill, a central pumping station giving the hydraulic pressure required. Under certain conditions this system promises excellent results.

An innovation at the works of one of the phosphate companies is the installation of a central plant to generate electric and hydraulic power for the mining operations. The results have proven eminently successful and under proper conditions the method promises to supersede the older and less economical ones.

The highest grade deposits with light overburden

foot rule, thus showing the thickness of the overlying strata. The rod is replaced in the bore hole, forced through the resisting stratum, and again withdrawn and measured, the difference between the first and second measurements being taken as representing the thickness of the phosphate bed. The bore holes are generally 100 feet apart, extending over the entire area of the land under examination. A series of exploring pits 10 feet long and 5 feet wide are dug at 500-foot intervals in order to verify and confirm the results obtained by the bore holes. The phosphate rock is carefully removed, the depth from the surface and the thickness of the bed is measured, and average samples of the rock and nodules are obtained for analysis. Throughout the area of the South Carolina field the strata overlying the phosphate rock are remarkably uniform. Heretofore, mining operations have been limited to material occurring not more than 15 feet from the surface, but there are larger areas containing phosphate rock at a greater depth than 15 feet whose value has not yet been determined.

The phosphate deposits of South Carolina are classified into river rock and land rock, the river rock, which is found in the beds of rivers, having been washed into them from the original land beds.

The river rock has been worked extensively and with considerable profit, for the reason that it is obtained by the simple and cheap process of dredging, which at the same time washes the rock free from adhering impurities. The dredging scoops are massive in construction in order to break through the stratum containing the nodules of phosphate rock. The boats are held in position by four "spuds," or strong, square iron-tipped poles, one at each corner. The nodules are thrown from the scoop into the washer which is generally on a lighter moored alongside of the dredge. Various kinds of washers are used, the one in common practice consisting of a truncated iron cone with perforated sides revolving on a horizontal axis and furnished on the inside with steel spirals like the grooves in a rifle barrel. The nodules are dumped by the dredge into the small end of the cone, heavy streams of water are introduced through both ends and the cone rotated; the washed material is discharged at the larger end of the cone and is removed by a derrick to another boat which carries it to the shore. The dredge generally used is of the ladder bucket type, which consists of a series of steel buckets connected by means of double links, the whole forming an endless chain which moves over drums or tumblers fixed at the ends of the ladder or frame. The higher end of the ladder is placed directly above the receiving hoppers and the lower end is supported by a tackle which allows it to be raised or lowered, according to the depth at which the work has to be done. The motive power is applied at the upper end by means of friction gear, so that any undue strain will not break the machinery. The ladder bucket dredge in the phosphate field ordinarily does not operate at depths greater than from 20 to 25 feet. Occasionally, for depths greater than 20 feet and up to 50 and 60 feet, a clam-shell bucket dredge is used, consisting of a contrivance of 4 or 6 iron claws which open as they are lowered and close forming a bucket as they ascend. The bucket, generally of about 1 cubic yard capacity, is operated from a swinging crane covering a radius of 25 feet in front of the scow; the material is delivered at a height of 14 feet above the deck into the receiving hoppers which feed into the washers. The cost of operating a clam-shell bucket dredge is from four to five times that of the ladder bucket dredge.

Both the rock and nodules from the river and land deposits occur in very irregular masses or blocks of extremely hard conglomerate of variegated colors, which weigh from half an ounce up to more than a ton.

The mean specific gravity of the material is 2.4, and the rock is perforated with a network of very small holes, the work of innumerable crustacea, now filled with sands and clays from the overlying strata. Sometimes the nodules are quite smooth or even glazed as if worn by water; in other cases they are rough or jagged.

The average analysis of South Carolina rock may be taken as follows:

		Per cent.
Tricalcic phosphate	$Ca_3(PO_4)_2$	59.63
Calcium carbonate	$CaCO_3$	8.68
Magnesium carbonate	$MgCO_3$	0.73
Iron and aluminum oxides	Fe_2O_3 and Al_2O_3	6.60
Sulphuric acid / Calcium fluoride	H_2SO_4 / CaF_2	4.80
Water and loss on ignition	H_2O	8.00
Silica and undetermined	SiO_2	11.56

The land rock occurs chiefly in the vicinity of Charleston, while the river rock is confined to the Coosaw river and other streams in the vicinity of Beaufort. The land rock contains from 57 to 60 per cent of tricalcic phosphate, but has also a higher percentage of iron and alumina than the river rock. That portion of the river rock which is low in iron and alumina is mainly shipped abroad.

The excellent quality of the South Carolina product, together with the favorable shipping conditions, place the production on a permanent basis, and the supply of reserve rock known at the beginning of the present decade is calculated to furnish a supply at present rate of consumption for thirty-five years to come. In recent years there has been a slight decrease in the annual production of river rock. The methods of mining and preparation have not changed materially during the past decade except that steam shovels are replacing hand labor for the removal of the overburden and the mining of the land rock. With regard to land rock, Francis Wyatt describes the method of treating it in order to make it marketable as follows: (1) mining or excavating, (2) washing to remove sand and other sterile impurities, and (3) drying in kilns to drive off the contained moisture.

Taking these in their order, it is customary to establish a trunk railroad, starting at the river front or on the bank of some convenient stream, and passing through the center of the property to be exploited. Alternate laterals can be run off at right angles from any portion of this main line, at a distance of say 500 feet, in conformity with the nature of the ground. Between and parallel to these laterals a ditch or drain is dug to a depth extending from 4 to 5 feet below the phosphate strata. From this main drain the excavators start their lines at right angles to the laterals, commencing at one end of the field and digging trenches 15 feet wide and 500 feet long, the work being so arranged that the men are stationed at intervals of 6 feet. Every man is supposed to dig out, daily, a pit 6 feet long, 15 feet wide, and down to the phosphate rock. The overlying material is thrown out to the left-hand side of the trench. The phosphate itself is thrown out to the right and taken in wheelbarrows to the railroad cars which pass at either end of the trench. The water drains from the trenches into the underlying ditch, and is thence pumped out by means of a steam pump worked by a locomotive engine. The pump and the engine are secured to connected railway platforms, and run along the railroad track from one ditch to another as occasion requires.

The cars loaded with the crude phosphatic material dug out of the pits are run down to the washing apparatus, which is constructed at an elevation of 30 feet from the ground, and generally consists of a series of semicircular troughs from 20 to 30 feet long set in an iron framework at an incline of about 20-inch rise in their length. Through every trough passes an octagonal iron-cased shaft provided with blades so arranged and distributed as to form a screw with a twist of 1 foot in 6, which forces the washed material upward and projects the fragments against each other. The phosphate-laden cars are hauled up an incline and their contents dumped into the bottom trough, where the phosphate encounters one or more heavy streams of water, pumped up by a steam pump. This water does not run off at the bottom, but overflows at the higher end near where it enters. When sufficiently washed the material is pushed out upon a half-inch mesh screen, the small débris being received on oscillating wire tables below.

The phosphate is now ready for kilning or drying, and of all the methods hitherto adopted for this important process, that of simple roasting in an ordinary kiln, such as is generally used in the manufacture of bricks, is said to have been found at once the most rapid, effective, and economical. The rock pile is built on layers of pine wood, and owing to its content of a considerable quantity of organic matter it readily lends itself to combustion and requires but a short time to become quite red hot. The kilns are made sufficiently large and are so arranged as to allow free passage to a train of cars, which, running on the main line of railroad, can be loaded in the kiln, run down to the landing place, and discharged directly into the barges or boats on the river.

The total production of phosphate rock in South Carolina, based on marketed output, from 1867 to and including 1902, as reported by the United States Geological Survey, is: Land rock, 6,702,139 long tons; river rock, 3,930,362 long tons; total, 10,632,501 long tons.

Tennessee.—Although the presence of phosphatic nodules in the Chattanooga shale had been known for several years, it was not until 1893 that the industry was started in Tennessee. The deposits are in Hickman and Lewis counties in the central part of the state, but in few places only are they of sufficient quantity and richness to admit of profitable working. The phosphates are classified according to color into blue, brown, and white. The blue rock deposits began to be developed in 1894 in Hickman and Lewis counties over an area of 10 by 20 miles, the principal deposits being adjacent to Swan Creek valley. The great drawback to the exploitation of the blue rock was the distance of the field from the railroad, being 20 miles away; this objection, however, might have been overcome, but the later discovery of the high-grade, easily-moved, brown phosphate rock near Mt. Pleasant, Maury county, 56 miles from Nashville, having direct railroad transportation to the market, reduced the mining of blue rock to inconsiderable proportions. The blue rock occurs in horizontal beds overlying and conforming to the country limestone; the workable beds average 18 inches in thickness and outcrop only where the streams have cut through the overlying strata. In a few cases it can be mined in open cuts by stripping the overburden, but the great bulk of the work must be mined under cover. With an 18-inch seam the mining cost, though high, is offset by the fact that the rock is sufficiently pure to be used without preliminary washing or screening; in fact it is stated to be the only deposit of phosphate yet found in the United States that can be mined and shipped without preliminary treatment. The average composition of the blue rock shows 70 per cent of tricalcic phosphate and from 2.5 to 3 per cent of iron and aluminum oxides. On account of its location away from the railroads the consumption of blue rock is local. With this blue rock occurs a so-called brown rock containing from 74 to 75 per cent of tricalcic phosphate and from 5 to 6 per cent of iron and aluminum oxides.

The general practice of mining is to strip the overburden by hand labor and to quarry the rock in lumps, or to run drifts into the deposit and remove the rock by the ordinary pillar and stall system. Should the material overlying the phosphate rock be such that only a little timbering is required, it will not ordinarily pay to remove the overburden unless it is less than 10 feet in thickness. Ordinarily the stripping of the overbur-

den is a simple matter for the reason that most of the phosphate rock deposits outcrop on a hillside. Generally the rock is crushed to pass through a 2-inch ring and is then treated in a revolving one-quarter-inch mesh screen in order to remove adhering clay and sand; the screened material is ground to from 60 to 80 mesh size and sold for direct use by the farmer or to small superphosphate manufacturers. The rock as it comes from the deposit is comparatively dry and contains on an average more than 60 per cent tricalcic phosphate.

Prior to 1896 the bulk of the production was obtained from the blue rock district where the mines have been developed to a considerable extent. The district was handicapped by long wagon haulage and comparatively costly underground work.

The Mt. Pleasant rock occurs over an area of from 3 to 4 miles north and south and from 6 to 8 miles east and west. There are two varieties—the soft, which constitutes the bulk of the supply, and the hard, which is of minor importance. The soft rock when dry varies in color from grayish or reddish brown to cream white, and occurs in plates of various thickness or size, rarely exceeding 2 or 3 feet in diameter. The plates are closely packed together into a fairly regular stratum which is not uniform in thickness and often sinks into depressions of the underlying limestone. The overburden averages 3 feet in thickness, except in the eastern part of the field where it is too thick in many places to admit of successful mining. The rock is of loose and porous texture and is readily ground when dry.

Two classes of product are made, known locally as domestic and export. The run of mine after the removal of the export lumps, is washed, kiln dried, crushed, and screened, the small particles and dust which pass through forming the domestic product, while the lumps constitute that exported. The export grade is guaranteed 78 per cent of tricalcic phosphate with a maximum of 4 per cent of iron and aluminum oxides; the domestic product is 75 per cent and 5 per cent of these components, respectively.

The hard rock is compact, heavy, oolitic in structure, yellow white in color, and occurs like the blue rock in a well-defined stratum of about two feet in thickness. It is of high grade, but occurs in small quantities. The Mt. Pleasant rock contains no pyrite, but little fluorite and usually a high content of tricalcic phosphate. Washing is necessary in order to remove the iron and aluminum oxides present in the crude rock as it comes from the mines. The mining at Mt. Pleasant is all open-cutwork. From 8 to 9 feet of overburden is removed by hand or with scrapers and the rock removed with pick and bar, no explosive being necessary. Usually the mined rock is dried, under sheds on a cribwork of cord wood, which is fired, yielding a thoroughly dry product. The dry rock is then crushed, screened, and stored or shipped. The high grade material is obtained chiefly from Mt. Pleasant and vicinity, while lower grade deposits exist in Hickman, Giles, and Sumner counties. For the former class of rock there is a good export market, but the low grade rock is consumed mostly at home.

The white rock deposits are in Perry county, the largest development being at Toms creek; it is far from the railroads, but is within 4 miles of the Tennessee river, which affords water transportation. The rock closely resembles Florida land rock in appearance and occurs with chert in pockets of variable size. Selected samples show a high content of tricalcic phosphate and low iron and aluminum oxides. On account of its unfavorable location but little work has been done on this property. White rock is found in other localities in Tennessee, but so far the deposits are of little, if any, importance.

Other states.—The geological survey of Alabama has examined several well-defined deposits, the chief one being the Hamburg bed in Perry county, which is part of a formation extending nearly across the state, although at only one or two points is the material of sufficient richness to make it of importance. The Coatopa bed in Sumter county has been traced for some distance. The Snow Hill bed in Wilcox and Marengo counties carries a higher percentage of tricalcic phosphate than either of the other deposits and holds out more promise of commercial value than any other in the state. There has been no production of phosphate rock in Alabama since 1900, in which year 334 long tons, valued at $534, were produced.

In Arkansas phosphate rock has been found in the counties of Independence, Stone, Izard, Baxter, Marion, Searcy, and Newton, in the northern part of the state, but little prospecting has been done, owing to the distance of the deposits from the railroads. The majority of the samples analyzed prior to 1902 showed a low content of tricalcic phosphate and were high in iron and aluminum oxides. In 1902 a large fertilizer plant was built near Batesville, on the White River Railroad, which was being extended to the mines. Mining operations have been begun in a layer of phosphate rock containing from 50 to 80 per cent of tricalcic phosphate and less than 3 per cent of iron and aluminum oxides. The deposits promise to be of considerable extent and richness, and they will doubtless be developed as soon as the railroad has been completed.

A deposit of phosphate rock has been reported near San Diego, Cal., but the samples sent east showed a small proportion of phosphoric acid and a large content of calcium carbonate.

In Georgia, according to S. W. McAllie, the only commercially important phosphate deposit is near Boston, Thomas county, which was discovered in 1889. The phosphate occurs in nodules of a size ranging from 1 inch to 1 foot in diameter, scattered promiscuously through a reddish sandy clay overlying an irregularly

eroded surface of limestone. In addition to the nodules, which contain from 70 to 78 per cent of tricalcic phosphate, there is also a small proportion of soft phosphate rock. A few carloads of rock were produced in 1889, but the work was abandoned on account of the small quantity of rock available and the great thickness of the overburden.

A small quantity of phosphate rock is mined annually at the shell-rock quarry, Castle Hayne, near Wilmington, N. C. The state owns the mines, and in 1897 proposed to work them with convict labor. In 1898 a land and improvement company was organized to take over the property under contract with the state. During recent years the entire product, which is of very low grade, has been used solely for macadamizing the streets of Wilmington.

The phosphate mines at Ross Farm, Juniata county, Pa., on the Tuscarora Valley Railroad, are operated by a fertilizer company, which erected a large plant for the manufacture of acid phosphate in 1898. The average rock is of low grade, but the good rock, containing more than 50 per cent of tricalcic phosphate, can be easily separated from that of poor grade. The phosphate beds dip steeply into the mountain, and the rock can be delivered at the works, 300 yards distant, at a very low cost.

In Virginia the occurrence of deposits of hard-rock phosphate was reported in Nelson county in 1893 and in Rockbridge county in 1894. An analysis of samples showed that the material was of high grade, but the deposits examined were so inaccessible and small that the rock could not be mined at a profit.

TABLE 6.—DETAILED SUMMARY: 1902.

	United States.	Florida.	South Carolina.	Tennessee.	All other states and territories.[1]
Number of mines or quarries	115	61	10	40	4
Number of operators	87	36	10	37	4
Character of ownership:					
Individual	18	7	.....	9	2
Firm	13	5	1	7	.....
Incorporated company	56	24	9	21	2
Salaried officials, clerks, etc.:					
Total number	391	192	80	115	4
Total salaries	$355,204	$206,108	$65,401	$82,125	$1,570
General officers—					
Number	64	32	9	23	.....
Salaries	$88,473	$53,000	$11,900	$23,573	.....
Superintendents, managers, foremen, surveyors, etc.—					
Number	253	118	61	71	3
Salaries	$213,983	$124,050	$45,221	$43,462	$1,250
Foremen below ground—					
Number	1	1	.....	.....	.....
Salaries	$275	$275	.....	.....	.....
Clerks—					
Number	73	41	10	21	1
Salaries	$52,473	$28,783	$8,280	$15,090	$320
Wage-earners:					
Aggregate average number	5,971	2,866	1,498	1,597	10
Aggregate wages	$1,930,093	$996,801	$435,553	$493,809	$3,930
Above ground—					
Total average number	5,901	2,858	1,498	1,535	10
Total wages	$1,906,293	$994,301	$435,553	$472,509	$3,930
Engineers, firemen, and other mechanics—					
Average number	513	320	156	36	1
Wages	$278,908	$180,982	$76,177	$21,269	$480
Miners or quarrymen—					
Average number	4,313	2,075	947	1,283	8
Wages	$1,312,379	$663,424	$258,537	$387,068	$3,350
Boys under 16 years—					
Average number	36	16	.....	19	1
Wages	$6,106	$2,749	.....	$3,257	$100
All other wage-earners—					
Average number	1,039	447	395	197	.....
Wages	$308,900	$147,146	$100,839	$60,915	.....
Below ground—					
Total average number	70	8	.....	62	.....
Total wages	$23,800	$2,500	.....	$21,300	.....
Miners—					
Average number	69	8	.....	61	.....
Wages	$23,600	$2,500	.....	$21,100	.....
Boys under 16 years—					
Average number	1	.....	.....	1	.....
Wages	$200	.....	.....	$200	.....
Average number of wage-earners at specified daily rates of pay:					
Engineers—					
$1.00 to $1.24	5	2	3	.....	.....
$1.25 to $1.49	5	1	3	.....	1
$1.50 to $1.74	52	34	16	2	.....
$1.75 to $1.99	3	2	1	.....	.....
$2.00 to $2.24	47	34	1	12	.....
$2.25 to $2.49	24	21	.....	3	.....
$2.50 to $2.74	20	10	9	1	.....
$2.75 to $2.99	1	1	.....	.....	.....
$3.00 to $3.24	11	2	9	.....	.....
Average number of wage-earners at specified daily rates of pay—Continued.					
Engineers—Continued.					
$3.50 to $3.74	2	1	1	.....	.....
$4.00 to $4.24	2	1	1	.....	.....
$4.25 and over	1	.....	1	.....	.....
Firemen—					
$0.75 to $0.99	14	.....	14	.....	.....
$1.00 to $1.24	76	43	32	1	.....
$1.25 to $1.49	37	34	3	.....	.....
$1.50 to $1.74	27	26	1	.....	.....
$1.75 to $1.99	3	2	1	.....	.....
$2.00 to $2.24	7	3	.....	4	.....
$2.25 to $2.49	1	1	.....	.....	.....
$2.50 to $2.74	4	.....	4	.....	.....
Machinists, blacksmiths, carpenters, and other mechanics—					
$0.50 to $0.74	1	.....	1	.....	.....
$0.75 to $0.99	20	.....	19	1	.....
$1.00 to $1.24	8	.....	8	.....	.....
$1.25 to $1.49	28	25	3	.....	.....
$1.50 to $1.74	25	18	3	4	.....
$1.75 to $1.99	4	2	2	.....	.....
$2.00 to $2.24	35	26	1	8	.....
$2.25 to $2.49	7	7	.....	.....	.....
$2.50 to $2.74	29	12	17	.....	.....
$3.00 to $3.24	6	4	2	.....	.....
$3.50 to $3.74	1	1	.....	.....	.....
$3.75 to $3.99	1	1	.....	.....	.....
$4.00 to $4.24	1	1	.....	.....	.....
$4.25 and over	5	5	.....	.....	.....
Miners or quarrymen—					
$0.50 to $0.74	6	1	5	.....	.....
$0.75 to $0.99	1,010	332	556	122	.....
$1.00 to $1.24	2,990	1,547	302	1,140	1
$1.25 to $1.49	226	72	71	76	7
$1.50 to $1.74	126	115	5	6	.....
$1.75 to $1.99	1	.....	1	.....	.....
$2.00 to $2.24	7	6	1	.....	.....
$2.25 to $2.49	1	1	.....	.....	.....
$2.50 to $2.74	2	1	1	.....	.....
$2.75 to $2.99	2	2	.....	.....	.....
$3.00 to $3.24	4	.....	4	.....	.....
$3.50 to $3.74	1	1	.....	.....	.....
$3.75 to $3.99	2	2	.....	.....	.....
$4.00 to $4.24	2	2	.....	.....	.....
$4.25 and over	2	1	1	.....	.....
Timbermen and track layers—					
$0.75 to $0.99	10	.....	10	.....	.....
$1.00 to $1.24	100	100	.....	.....	.....
$1.75 to $1.99	1	.....	1	.....	.....
Boys under 16 years—					
Less than $0.50	7	6	.....	.....	1
$0.50 to $0.74	27	7	.....	20	.....
$0.75 to $0.99	2	2	.....	.....	.....
$1.00 to $1.24	1	1	.....	.....	.....
All other wage-earners—					
Less than $0.50	45	.....	44	1	.....
$0.50 to $0.74	55	.....	54	1	.....
$0.75 to $0.99	232	33	189	10	.....
$1.00 to $1.24	476	203	96	177	.....
$1.25 to $1.49	82	77	1	4	.....
$1.50 to $1.74	20	19	.....	1	.....
$1.75 to $1.99	13	12	.....	1	.....
$2.00 to $2.24	5	3	.....	2	.....

[1] Includes operators distributed as follows: Arkansas, 1; New Mexico, 1; Ohio, 1; and Pennsylvania, 1.

TABLE 6.—DETAILED SUMMARY: 1902—Continued.

	United States.	Florida.	South Carolina.	Tennessee.	All other states and territories.
Average number of wage-earners employed during each month:					
Men 16 years and over—					
January	5,562	2,857	1,531	1,167	7
February	5,336	2,739	1,517	1,073	7
March	5,521	2,745	1,529	1,240	7
April	5,841	2,794	1,621	1,419	7
May	5,944	2,838	1,492	1,607	7
June	6,368	2,873	1,422	2,066	7
July	6,335	2,847	1,481	1,994	13
August	6,322	2,876	1,594	1,833	19
September	6,403	2,866	1,556	1,968	13
October	6,081	2,942	1,432	1,700	7
November	5,777	2,899	1,388	1,483	7
December	5,718	2,924	1,413	1,374	7
Boys under 16 years—					
January	30	10	.....	19	1
February	30	10	.....	19	1
March	30	10	.....	19	1
April	42	21	.....	20	1
May	41	21	.....	19	1
June	42	21	.....	20	1
July	43	22	.....	20	1
August	42	21	.....	20	1
September	39	18	.....	20	1
October	39	18	.....	20	1
November	33	10	.....	22	1
December	33	10	.....	22	1

	United States.	Florida.	South Carolina.	Tennessee.	All other states and territories.
Contract work:					
Amount paid	$157,402	.....	.....	$157,402	.....
Number of employees	306	.....	.....	306	.....
Miscellaneous expenses:					
Total	$430,475	$283,149	$65,157	$81,882	$287
Royalties and rent of mine and mining plant	$212,350	$120,143	$38,333	$53,754	$120
Rent of offices, taxes, insurance, interest, and other sundries	$218,125	$163,006	$26,824	$28,128	$167
Cost of supplies and materials	$799,414	$542,322	$162,836	$93,715	$541
Product:					
Quantity, long tons	1,548,720	786,115	327,557	432,603	2,445
Value	$4,922,943	$2,655,463	$950,208	$1,308,872	$8,400
Power owned:					
Total horsepower	14,229	9,529	3,070	1,410	220
Engines—					
Steam—					
Number	282	192	70	18	2
Horsepower	13,974	9,359	3,070	1,325	220
Water wheels—					
Number	1	1	.....	.....	.....
Horsepower	170	170	.....	.....	.....
Other power—					
Number	2	.....	.....	2	.....
Horsepower	85	.....	.....	85	.....
Electric motors—					
Number	9	9	.....	.....	.....
Horsepower	500	500	.....	.....	.....

SULPHUR AND PYRITE

SULPHUR AND PYRITE.

By Joseph Struthers, Ph. D.

The statistics for the sulphur and pyrite industries have been united in the present discussion in order not to disclose the operations of 1 company engaged in producing sulphur. Table 1 is a summary of the combined statistics for these 2 industries in 1889 and 1902, and of the statistics of pyrite alone for 1880, no returns for sulphur mining having been made for that year. The expansion of domestic production to meet the increasing demand for sulphur and sulphuric acid is clearly indicated.

Table 1.—*Comparative summary: 1880 to 1902.*

	1902	1889	1880
Number of mines	23	2	1
Number of operators	18	(1)	1
Salaried officials, clerks, etc.:			
Number	54	(2)	(1)
Salaries	$49,890	$5,512	(1)
Wage-earners:			
Average number	970	249	6
Wages	$398,870	$64,789	$1,200
Contract work	$3,587	$23,103	(1)
Miscellaneous expenses	$39,118	$30,262	(1)
Cost of supplies and materials	$217,262	$43,700	$365
Product:[3]			
Quantity, long tons	207,874	106,100	2,240
Value	$947,089	$209,969	$5,000

[1] Not reported.
[2] Not reported separately.
[3] Includes in 1902, 11,483 tons of pyrite, valued at $29,420, produced as a by-product of coal mining.

For the twenty-two years covered, the table shows an increase in production of over one-hundredfold, and in value of nearly one hundred and ninety fold. When the total amount of sulphur consumed (as sulphur, not including pyrite) is taken into consideration, the amount of the domestic production in 1902 was not relatively large, but the steady increase indicates the substantial nature of the industry. In 1880 the industry was small—only 1 pyrite mine with a product valued at $5,000 being reported, but in 1889 the value of the production of sulphur and pyrite was $209,969. This increased to $947,089 in 1902. The growth from 1880 to 1889 was greater proportionately, but that from 1889 to 1902 was larger in absolute amount.

Three sulphur mines were reported idle in 1902—1 in Colorado and 2 in Utah; and 5 pyrite mines—1 each in Alabama and Ohio, and 3 in Virginia. At 1 sulphur mine in Texas development work was reported.

Capital stock of incorporated companies.—Of the 18 operators in the United States in 1902, 14 were organized as incorporated companies. The details of their capitalization are shown in Table 2.

Table 2.—*Capitalization of incorporated companies: 1902.*

	United States.	Virginia.	All other states.
Number of incorporated companies	14	2	[1] 12
Number reporting capitalization	12	2	[2] 10
Capital stock:			
Total authorized—			
Number of shares	46,000	12,500	33,500
Par value	$4,260,000	$1,250,000	$3,010,000
Total issued—			
Number of shares	38,850	7,500	31,350
Par value	$3,545,000	$750,000	$2,795,000
Dividends paid	$2,400	.....	$2,400
Common—			
Authorized—			
Number of shares	42,500	12,500	30,000
Par value	$3,910,000	$1,250,000	$2,660,000
Issued—			
Number of shares	37,500	7,500	30,000
Par value	$3,410,000	$750,000	$2,660,000
Dividends paid	$2,400	.....	$2,400
Preferred—			
Authorized—			
Number of shares	3,500	.....	3,500
Par value	$350,000	.....	$350,000
Issued—			
Number of shares	1,350	.....	1,350
Par value	$135,000	.....	$135,000

[1] Includes companies distributed as follows: Alabama, 1; California, 2; Louisiana, 1; Massachusetts, 1; Missouri, 1; Nevada, 1; New York, 1; Ohio, 3; Washington, 1.
[2] Includes companies distributed as follows: Alabama, 1; Louisiana, 1; Massachusetts, 1; Missouri, 1; Nevada, 1; New York, 1; Ohio, 3; Washington, 1.

These companies reported a total capital stock issued of a par value of $3,545,000. This was made up of 37,500 shares of common stock, 88 per cent of the number authorized, having a par value of $3,410,000, which is 87 per cent of the total par value of the $3,910,000 authorized; and 1,350 shares of preferred stock having a par value of $135,000, these amounts being each 90 per cent of the number of shares and total value of the preferred capital stock authorized. There was no bonded indebtedness.

Employees and wages.—The average number of wage-earners employed each month during 1902 is shown in Table 6. The employment was comparatively steady. The average number of wage-earners for the entire year was 970. The highest monthly average, 1,059, reported in July, exceeds this by only 89, and the lowest, reported in December, falls short of it by 151, a total variation of 240, or 24.8 per cent of the yearly average. Child labor constituted only 13.4 per cent of the whole.

Table 6 shows also the average number of wage-earners employed at specified daily rates of pay during 1902.

The rate group comprising the greatest number of wage-earners is that from $1 to $1.24 per diem, 30 per cent of the entire number being included within these rates. Of the employees, 205, or 21.1 per cent, received from $1.25 to $1.49 per day; 662, or 68.2 per cent got between $1 and $1.74 per day; 146, or 15 per cent of the total, were employed at a rate of $2 or more, and 117, or 12.1 per cent, received less than $1 per diem. Of the 970 wage-earners, 429, or 44.2 per cent, were employed below ground. Miners and quarrymen numbered 301, or 31 per cent, and 110, or 36.5 per cent of these, received from $1.25 to $1.49 per day, the remainder being distributed mostly among the higher rate groups, 6 receiving from $3 to $3.24. "All other wage-earners" numbered 405, or 41.8 per cent, their greatest concentration, 48.1 per cent, being in the rate group from $1 to $1.24.

Mechanical power.—The primary power reported for the sulphur and pyrite industry aggregated 6,305 horsepower. Of this 5,915 horsepower was generated by steam, 20 by gas or gasoline, 50 by rented waterpower, and 320 by air compressors. Two electric motors, having a capacity of 80 horsepower, were also reported.

Production.—In the following table the figures for the domestic production and the imports of sulphur and pyrite are given, so far as obtainable, for the years 1880 to 1902. The statistics for the two minerals are presented separately except for 1902, a combination for that year being necessary to avoid disclosing the operations of a company engaged in producing sulphur. The quantity of sulphur displaced by the use of pyrite is also shown.

TABLE 3.—ANNUAL DOMESTIC PRODUCTION, IMPORTS, AND TOTAL CONSUMPTION OF SULPHUR AND OF PYRITE, WITH PERCENTAGE DOMESTIC PRODUCTION IS OF TOTAL CONSUMPTION, AND QUANTITY OF SULPHUR DISPLACED BY PYRITE: 1880 TO 1902.

[United States Geological Survey, "Mineral Resources of the United States," 1902.]

YEAR.	SULPHUR.						PYRITE.						Quantity of sulphur displaced by use of pyrite (long tons).[2]
	Total consumption (long tons).	Domestic production.			Imports.		Total consumption (long tons).	Domestic production.			Imports.[1]		
		Quantity (long tons).	Value.	Per cent of total consumption.	Quantity (long tons).	Value.		Quantity (long tons).	Value.	Per cent of total consumption.	Quantity (long tons).	Value.	
1880	88,655	536	$21,000	0.6	88,119	$2,034,899	.....	.....	.....	.....	.....	.....	.....
1881	105,802	536	21,000	0.5	105,266	2,720,266	.....	.....	.....	.....	.....	.....	.....
1882	98,258	536	21,000	0.6	97,722	2,636,524	.....	12,000	$72,000	.....	.....	.....	.....
1883	95,627	893	27,000	0.9	94,734	2,296,695	.....	25,000	137,500	.....	.....	.....	.....
1884	105,862	446	12,000	0.4	105,416	2,255,381	51,710	35,000	175,000	67.7	16,710	$50,632	.....
1885	97,712	638	17,875	0.7	97,074	1,951,354	55,078	49,000	220,500	89.0	6,078	18,577	.....
1886	120,099	2,232	75,000	1.9	117,867	2,250,605	56,605	55,000	220,000	97.2	1,605	9,771	.....
1887	99,924	2,679	100,000	2.7	97,245	1,700,723	68,578	52,000	210,000	75.8	16,578	49,661	.....
1888	98,407	.....	.....	.....	98,407	1,586,519	.....	54,331	167,658	.....	.....	.....	.....
1889	136,360	402	7,850	0.3	135,958	2,070,461	.....	93,705	202,119	.....	.....	.....	.....
1890	162,789	.....	.....	.....	162,789	2,767,731	.....	99,854	273,745	.....	.....	.....	.....
1891	118,258	1,071	39,600	0.9	117,187	2,683,971	207,184	106,536	338,880	51.4	100,648	392,141	93,233
1892	103,522	2,400	80,640	2.3	101,122	2,199,026	262,147	109,788	305,191	41.9	152,359	587,980	117,966
1893	106,894	1,071	42,000	1.0	105,823	1,909,961	270,711	75,777	256,552	28.0	194,934	721,699	121,820
1894	125,905	446	20,000	0.4	125,459	1,708,617	269,486	105,940	363,134	39.3	163,546	590,905	121,269
1895	123,703	1,607	42,000	1.3	122,096	1,613,754	289,984	99,549	322,845	34.3	190,435	673,812	130,493
1896	143,976	4,696	87,200	3.3	139,280	2,172,629	315,651	115,483	320,163	36.6	200,168	648,396	142,043
1897	143,936	2,031	45,590	1.4	141,905	2,454,073	402,747	143,201	391,541	35.6	259,546	747,419	181,236
1898	165,575	1,071	32,960	0.7	164,504	3,069,924	446,137	193,364	593,801	43.3	252,773	717,813	200,762
1899	145,846	4,313	107,500	3.0	141,533	2,523,203	444,602	174,734	543,249	39.3	269,868	1,077,061	200,071
1900	170,843	3,147	88,100	1.8	167,696	2,940,888	527,099	204,615	749,991	38.8	322,484	1,055,121	237,195
1901	182,076	6,866	223,430	3.8	175,210	3,287,906	638,531	234,825	1,024,449	36.8	403,706	1,415,149	287,339
1902	(3)	(3)	(3)	(3)	174,939	3,283,309	[3] 648,237	[3] 207,874	[3] 947,089	.....	440,363	1,650,852	(3)

[1] Previous to 1884 classed among sulphur ores; 1887 to 1891 classed among other iron ores; since 1891 includes iron pyrite containing 25 per cent or more of sulphur.
[2] Estimated on basis of 45 per cent sulphur content.
[3] The statistics of the domestic production and total consumption of sulphur are combined with those of pyrite to avoid disclosing the operations of a company producing sulphur.

The quantity of sulphur produced each year in this country has been a relatively small part of the total consumption of the commodity. In no year during the period covered by the table has this proportion exceeded 3.8 per cent, but a comparison of the fluctuation makes it evident that this proportion tends to increase. The imports have increased from 88,119 long tons in 1880 to 174,939 long tons in 1902.

Practically all the pyrite consumed in 1882 was of domestic production, but in 1901 this source yielded only 36.8 per cent of the total. Owing to trade conditions the foreign pyrite can be more profitably utilized than can the domestic ore. Hence the imports have constantly grown until they now form almost two-thirds of the total consumption.

The recovery of the sulphur content of pyrite has steadily encroached upon the field formerly occupied almost exclusively by sulphur. Estimated on an average sulphur content of 45 per cent, the quantity of sulphur displaced by the use of pyrite has grown from

93,233 long tons in 1891 to 287,339 long tons in 1901. This latter figure exceeds the domestic production of sulphur by 280,473 long tons.

Imports of sulphur.—Table 4 shows the importation of sulphur into the United States for 1900, 1901, and 1902, the exporting countries, and the customs district at which the sulphur was entered.

TABLE 4.—IMPORTS, BY COUNTRIES AND BY CUSTOMS DISTRICTS, INTO THE UNITED STATES, OF CRUDE SULPHUR OR BRIMSTONE, FOR THE FISCAL YEAR ENDING JUNE 30: 1900 TO 1902.

[United States Geological Survey, "Mineral Resources of the United States," 1902.]

	1900		1901		1902	
	Quantity (long tons).	Value.	Quantity (long tons).	Value.	Quantity (long tons).	Value.
COUNTRY.						
Total	155,399	$2,711,912	159,711	$2,875,104	187,480	$3,582,884
Canada	.....	.....	933	24,957	776	18,631
England	7,425	155,882	7,484	156,205	7,681	161,387
Italy	138,011	2,369,037	139,492	2,474,684	163,571	3,111,971
Japan	9,958	186,847	11,798	219,193	15,448	290,826
Other countries	5	146	4	65	4	69
DISTRICT.						
Total	155,399	2,711,912	159,711	2,875,104	187,480	3,582,884
Baltimore, Md	12,798	213,893	9,040	153,664	12,137	225,804
Boston and Charlestown, Mass	10,023	203,014	11,048	217,274	12,124	251,366
Champlain, N. Y	.....	.....	.....	.....	.....	.....
New Orleans, La	1,000	16,111	2,213	54,694	.....	.....
New York, N. Y	85,885	1,467,947	89,756	1,585,084	100,109	1,891,554
Philadelphia, Pa	7,448	120,284	11,100	185,319	16,719	304,777
Portland, Me	24,880	436,692	20,039	363,473	30,032	596,931
San Francisco, Cal	8,237	152,835	9,359	172,176	10,497	200,255
Savannah, Ga	751	13,675	1,000	18,190	.....	.....
Vermont	.....	.....	439	12,285	.....	.....
Willamette, Oreg	1,630	33,134	2,087	40,515	3,475	63,696
All other	2,747	54,827	3,630	72,430	2,387	48,501

Relative production of sulphur by various countries.—In order to show the production of sulphur by the different countries of the world, the following table has been compiled from data gathered by the United States Geological Survey. This table indicates that nearly 90 per cent of the world's production of sulphur is obtained from Italy.

TABLE 5.—*World's production of sulphur: 1899, 1900, and 1901.*

[United States Geological Survey, "Mineral Resources of the United States," 1902.]

COUNTRY.	1899		1900		1901	
	Quantity (metric tons).	Value.	Quantity (metric tons).	Value.	Quantity (metric tons).	Value.
Total	645,044	$10,946,838	641,809	$10,809,041	634,761	$11,149,937
United States	4,383	107,500	3,199	88,100	6,976	223,430
Austria[1]	555	1,526	862	2,256	4,911	12,107
France[1]	11,744	28,884	11,551	26,427	7,000	16,400
Germany	1,663	36,000	1,445	31,000	963	20,250
Greece	1,237	22,266	891	16,038	3,212	67,290
Hungary	116	3,000	123	3,820	137	3,847
Italy	554,638	10,392,415	544,119	10,212,903	563,096	10,734,192
Japan	10,235	211,735	14,435	298,660	(2)	(2)
Russia	451	9,412	(2)	(2)	(2)	(2)
Spain	1,100 158,922	31,350 102,150	750 164,364	18,000 109,947	610 149,856	13,115 59,306
Sweden	.....	.....	70	1,890	.....	.....

[1] Crude rock. [2] Statistics not yet reported.

A detailed summary of the industry is given in Table 6.

DESCRIPTIVE.

SULPHUR.

Sulphur has been known to mankind from the earliest records of history. It is one of the most important elements that comprise the earth's crust, and occurs in a free or uncombined state in many countries, forming the mineral sulphur, more commonly known in commerce as brimstone.

Physical and chemical characteristics.—The element is insoluble in water and nearly so in alcohol and ether, but is quite soluble in carbon disulphide, petroleum, and benzine. It burns in air with a blue flame, and is oxidized into sulphur dioxide or sulphurous acid. It exists in two distinct crystalline forms, and also as an amorphous variety. These modifications are characterized by differences in specific gravity, in solubility in various liquors, and in many other respects.

Sulphur is a pale-yellow, brittle, crystalline solid, with a resinous luster, is almost tasteless, and emits a peculiar characteristic odor when rubbed or warmed. It is a nonconductor of electricity and an extremely bad conductor of heat. When very gently warmed, even by being grasped in the hand, it may be heard to crack by the mere warmth, and will ultimately fall to pieces. At a temperature of 114.5° C. it melts into a clear amber-colored and moderately mobile liquid; on raising the temperature of this liquid, its color rapidly darkens, and at the same time it loses its mobility until

at a temperature of about 230° C. the mass appears almost black, and is so viscous that it can no longer be poured from the vessel. As the temperature is still further raised the substance, while retaining its dark color, again becomes liquid, although it does not regain its former limpidity. At 448° C. the liquor boils and is converted into a pale yellowish-brown colored vapor. In cooling the same changes occur in reverse order. The atomic weight is 32. The specific gravity of ordinary octahedral sulphur is 2.05; of prismatic sulphur, 1.96.

Uses.—Sulphur is used in the preparation of sulphuric acid, in the manufacture of gunpowder, in making friction matches, in vulcanizing rubber, as an insecticide, and in medicine as a laxative, and for certain skin diseases.

Minerals of sulphur.—Sulphur occurs in combination with other elements, forming the large and important groups of minerals, the sulphides and the sulphates. Of the sulphide minerals, the combinations with the metallic elements are of primary industrial importance, and, with the possible exception of the iron sulphides, they form the ores from which many of the base metals are obtained.

The principal sulphide and sulphate combinations are as shown below.

Sulphide and sulphate combinations.

COMBINATION OF ELEMENTS.	Name of mineral.	Chemical formula.
Chief sulphide minerals:		
Sulphur and iron	Pyrite	FeS_2
Sulphur and iron	Marcasite	FeS_2
Sulphur and iron	Pyrrhotite	$Fe_{11}S_{12}$
Sulphur and copper	Chalcocite	Cu_2S
Sulphur and copper and iron	Chalcopyrite	$CuFeS_2$
Sulphur and copper and iron	Bornite	Cu_3FeS_3
Sulphur and lead	Galenite (galena)	PbS
Sulphur and zinc	Sphalerite (zinc blende)	ZnS
Sulphur and silver	Argentite	Ag_2S
Less important sulphide minerals:		
Sulphur and arsenic	Realgar	AsS
Sulphur and arsenic	Orpiment	As_2S_3
Sulphur and antimony	Stibnite	Sb_2S_3
Sulphur and molybdenum	Molybdenite	MoS_2
Sulphur and mercury	Cinnabar	HgS
Sulphur and nickel	Millerite	NiS
Sulphur and tin	Tin pyrites	SnS_2
Chief sulphate minerals:		
Sulphur and calcium	Gypsum	$CaSO_4 2H_2O$
Sulphur and calcium	Anhydrite	$CaSO_4$
Sulphur and barium	Barite	$BaSO_4$
Sulphur and magnesium	Epsomite (Epsom salt)	$MgSO_4 7H_2O$
Sulphur and strontium	Celestite	$SrSO_4$
Sulphur and sodium	Thenardite (Glauber salt).	Na_2SO_4
Sulphur and lead	Anglesite	$PbSO_4$
Important artificial sulphates:		
Sulphur and copper	Copper sulphate (blue vitriol).	$CuSO_4 7H_2O$
Sulphur and iron	Iron sulphate (copperas).	$FeSO_4 7H_2O$
Sulphur and zinc	Zinc sulphate (white vitriol).	$ZnSO_4 7H_2O$

Sulphur dioxide (SO_2) is the direct combination of sulphur with oxygen and is found naturally as a minor constituent of the atmosphere, particularly near volcanoes, and over large cities, where its presence is due to the oxidation of the sulphur contained in the fuel burned.

In vegetables sulphur exists in some of the tissues of plants, although not in the woody tissues. In animals it constitutes an essential element of the blood, muscles, skin, hair, and other parts.

Hydrogen sulphide (H_2S) and sulphur dioxide (SO_2) are evolved from volcanoes as gases, which are doubtless the products of the action of the water of the ocean which has penetrated to the interior of the volcano upon the molten metallic sulphides that exist there.

The two forms in which the sulphur is marketed are the flour, or flowers, of sulphur, which is a light powdery form of the substance caused by the condensation of sulphur vapor; and brimstone, or sulphur, which is made usually by melting this soft powder and molding the liquid thus obtained into large blocks or cylindrical rods in wooden molds.

Occurrence.—Natural deposits of sulphur are sometimes found stratified with beds of clay or rock, but they often occur as what are known as "living" beds, in which the sulphur is continuously being formed as the result of active chemical decompositions. In such a living sulphur bed the sulphur is produced by the direct action of sulphurous gases, especially hydrogen sulphide (H_2S) and sulphur dioxide (SO_2), which in the presence of moisture (H_2O) react and form water (H_2O) and sulphur (S). These gases emanate in regions of active or expiring volcanoes, and form the so-called solfataras, in which the sulphur has been condensed from the vapors formed and has collected in cracks in the lava and tuffs or in the kaolin or clay formed by the corroding action of the acid vapors on the lavas.

From a commercial standpoint, especially for the manufacture of sulphuric acid, the mineral from the solfatara deposits is not regarded favorably on account of its liability to contain arsenic in the form of the minerals orpiment (As_2S_3) and realgar (AsS). Sulphur of this character has been imported from the island of Vulcano, one of the Lipari group, off the coast of Italy. A similar association of arsenic minerals has been reported in the sulphur deposits in Yellowstone National Park. Traces of selenium and tellurium, which are also objectionable in the manufacture of sulphuric acid, occur in the volcanic sulphur deposits in Japan. The only solfatara deposits of commercial importance at the present time are in southern Utah and in the island of Hokkaido, Japan.

The world's supply of sulphur is derived from two principal sources: (1) The deposits of the native mineral sulphur, which yield the sulphur or brimstone of commerce; and (2) the deposits of the sulphide minerals—pyrite, pyrrhotite, chalcopyrite, sphalerite, and other sulphides—from which is derived the sulphur dioxide gas used in the manufacture of sulphuric acid. In addition to these two natural sources of sulphur, there are several artificial products containing sulphur, chiefly in the form of sulphur dioxide gas, in sufficient quantity to admit of commercial utilization. There are also lead, copper, and other mattes from the furnace

treatment of various lead and copper ores and alkali waste from chemical works engaged in manufacturing soda.

During recent years, however, several thousand tons of sulphur have been produced annually in England from the accumulated alkali waste of the Le Blanc soda process. This manufactured product is known as "chance-claus," or recovered sulphur. The process of its manufacture reproduces, in many respects, the chemical reactions by which natural sulphur is formed from gypsum.

REVIEW OF THE INDUSTRY IN THE UNITED STATES.

The development of the sulphur mining industry in the United States has been of very slow growth, owing principally to the cheapness with which the refined product can be imported from Italy. In recent years nearly the entire supply has been obtained from the enormous deposits in the island of Sicily, which supplies, as well, by far the greater part of the rest of the world's demand. The deposits of sulphur which have been worked in the United States are limited in number. The states from which, during 1902, the domestic supply of native sulphur was derived are, in the order of the quantity of their output, Louisiana, Nevada, and Utah.

The following is a brief summarization of the progress that has been made in extracting and refining the sulphur of the deposits in this country.

Louisiana.—An immense deposit of sulphur of the gypsum type occurs in Calcasieu parish, 230 miles west of New Orleans and 12 miles from Lake Charles. This is unquestionably the most accessible of the American deposits, and, in all probability, it is the richest as well. Exceptional difficulties have been encountered in developing the mine, owing to quicksand and gravel which overlie the mineral. As proved by a number of drill holes, the bed of sulphur is from 110 to 125 feet in thickness, the upper level being about 350 feet below the surface.

In the working of the Frasch process,[1] a well is sunk by a drill precisely in the same way as for petroleum.[2] This well is cased with an iron pipe 10 inches in diameter, which enters the rock overlying the bed of sulphur for a distance of 10 feet, the joint being subsequently sealed as well as possible by molten sulphur in order to exclude water. Inside the 10-inch pipe is placed one of 6-inch diameter; inside the latter, one of 3-inch diameter; and, finally, inside the 3-inch pipe, one of 1-inch diameter. The well itself is carried down to the bottom of the sulphur bed, and the 6-inch and smaller pipes are extended nearly to the bottom of the well. The inner pipes are recovered when the well is abandoned. The method of extracting the sulphur is as follows: Steam at a temperature of 330° F. is forced down the 10-inch and 6-inch pipes under a corresponding pressure. When the steam comes in contact with the sulphur (which at 284° F. becomes liquid), the latter melts and collects in the well as a thin liquid of a specific gravity of about 2. At first the molten sulphur was pumped out through the 3-inch pipe in a manner similar to that followed in pumping petroleum from a well, the working valve being formerly of aluminum, which is not affected by sulphur. It was found, however, that the aluminum was not strong enough to withstand the shock of the heavy column at the change of stroke, and the method had to be abandoned. Later, the 1-inch pipe referred to above was introduced into the 3-inch pipe, and through it compressed air was forced. The bubbles of air mixed with the sulphur reduce the specific gravity of the column of sulphur and cause it to rise with rapidity. This latter method of extraction has not been entirely satisfactory, and it may have been modified or replaced by some other more efficient method. The sulphur produced is practically refined sulphur, and finds a ready sale on account of its purity and attractive appearance.

It is not practicable to ascertain precisely what occurs at the bottom of the well, but it may be assumed that as the sulphur melts out of the bed it forms a more or less pear-shaped cavity, which becomes larger and larger, until finally the increased surface exposed to the water is sufficiently great to reduce the temperature of the water below the melting point of the sulphur, while the impurities of the bed collect on the bottom and the sides of the chamber and protect the sulphur still unfused from the melting action of the heated water. If the bed of sulphur is very pure the chamber might become quite large in size, when the unsupported overlying roof would fall and allow the water to escape through the overlying beds.

Although the Frasch process is very ingenious and the inventor deserves great credit for working out the numerous details, yet its application to the deposits of sulphur has greatly injured them, since the exploitation of the deposit by shafts and the common method of underground mining has now become fraught with danger, owing to the uncertain extent of the openings from which the sulphur has been dissolved by the Frasch experiments. In view of the heavy flow of water which may be expected through certain of the strata this uncertainty is an element of great peril.

Nevada.—Sulphur occurs at Rabbit Hole Springs, 35 miles from Humboldt House, in Humboldt county. The deposit is of the solfatara type; and the sulphur, associated with gypsum, etc., fills the craters of a few extinct hot springs. The sulphur rock is in beds of considerable thickness and extent, included between limestone and magnesian rocks. The ore occurs in masses of various sizes up to several hundred pounds in weight, which are mixed with clay among heaps and

[1] United States patents, Nos. 461429, 461430, and 461431 of October 20, 1891.

[2] The Mineral Industry, Vol. V, pages 514 and 515.

layers of ashes and light gravel. The ore is mined by adits and drifts run in from the level of the wagon road, which extends entirely around the hill at a considerable elevation. All rock containing more than 8 per cent of sulphur is mined, and the product is taken to the refinery and refined in iron kettles heated by dry steam. The refined product is carried in wagons to Humboldt House and shipped thence by rail, chiefly to the powder factories and acid makers on the Pacific coast.

Utah.—The deposits which are the source of most of the sulphur mined in Utah are located in Beaver county near the Millard county line. They were known to the early pioneers, who obtained small quantities of almost pure sulphur from the numerous caves in that vicinity. Soon after the year 1870 the claims were located under the mining laws, and a small refining furnace was installed which was worked intermittently until the year 1891, when the property changed owners, and the plant was modernized and enlarged. Under the new management, the mining operations of the company have been continuous and successful. The ore is removed by open cutting, and the furnaces are worked during the summer only. Four of the six stacks in the refining plant are generally operated at a time, and about 50 tons of 20 per cent rock are treated daily, yielding the refined product in the form of roll sulphur, which is sold as such or is ground in mills to make flour sulphur.

Deposits in other states and in Alaska are thus described:

Alaska.—There are a number of sulphur deposits of the solfatara type on the volcanic islands off the coast of Alaska. The largest so far as known is on the island of Kadiak, but others are recorded on Unalaska and Akutan islands, and on an unnamed island southeast of Akun Island. The deposits have not yet been exploited beyond the prospecting stage.

California.—At Sulphur Bank, on Clear Lake, 40 miles north of San Francisco, a deposit of sulphur occurs in the white siliceous residue of a basalt flow that has been decomposed by the uprising solfatara and the sulphur deposited. Some 25 years ago this deposit contributed a small quantity to the domestic supply of the United States, but as the development work went deeper cinnabar was found, and sulphur was no longer produced. A deposit of sulphur was worked for a time in Colusa county, and a small refinery was erected, but during the past decade little, if any, sulphur has been produced in this county. The occurrence of sulphur has also been reported in other localities in California, but nowhere in sufficient quantity to warrant its extraction as a commercial product.

Idaho.—The occurrence of sulphur has been reported near Swan Lake, Custer county, and also near Soda Springs, in Bannock county. The deposits have not yet been developed to any great extent, although there was a small output in 1901.

Texas.—The sulphur deposits in the northeastern part of El Paso county have been known since 1854, when they were noticed by Prof. William P. Blake, who was then the geologist of an expedition for the survey of a railroad route from the Mississippi river to the Pacific ocean, which was made by the United States War Department. The region in which the deposits occur is from 13 to 60 miles from the railroad. The nearest railroad station, Guadalupe, on the Pecos Valley Railroad, is 42 miles north of Pecos. The sulphur occurs in the form of small crystals embedded in white gypsum, and in some instances the ore contains as much as 25 per cent of native sulphur. The area of the region thus far prospected is small, but there are other localities of promise awaiting examination.

Method of refining sulphur.—It has been proposed to separate sulphur from the ore by heating it with hot air, with steam under pressure, or with superheated steam. But these methods have been unprofitable on account of the cost of fuel in those regions where sulphur occurs. Sulphur may be extracted from the ore by a solvent, such as carbon disulphide, which may be recovered afterwards, but this method necessitates an expensive plant. For some ores a treatment with a solution boiling above the melting point of sulphur has proved successful. The ore is placed in an iron basket or crate in a boiling solution of calcium chloride,[1] which boils at 125° C. The sulphur melts and flows away from the matrix of stones, etc.; passing through the meshes of the basket and falling to the bottom of the tank, it is drawn off and cast in molds. After it is melted out, the basket of hot stones is lowered into a tank of water, which is heated by the stones, while it removes the adhering calcium chloride from them. This warm water is then used to replace that lost from the boiling calcium chloride solution. This process causes no loss of sulphur as sulphur dioxide, and no nuisance is created, while a fairly pure product is obtained. The calcium chloride used is a waste product of the ammonia soda industry.

In the United States, the extraction of sulphur by means of superheated steam[2] has been tried, and an excellent quality of sulphur has been obtained without formation of any sulphur dioxide. The cost of fuel in the West, however, is an obstacle to the further development of this method. In Louisiana, as mentioned earlier in this paper, steam is forced, under pressure, through driven wells or tubes, into the sulphur deposit, which partly refines the sulphur, liquefied by the heat. The molten product is forced to the surface by the

[1] Vincent: Bull. Soc. Chim., 40, 528. Am. Chem. Jour., VI, 63.
[2] J. Soc. Chem. Ind., 1887, 439, 442; 1889, 696.

steam pressure through a small pipe inside of the steam pipe.

Generally the method of extracting the sulphur from the ore, and at the same time of partially refining it, is to treat the ore in a cylindrical or slightly conical cast-iron vessel of a capacity of about 5 tons of ore. Steam inlets are provided at the top and bottom; also a bottom valve through which the melted sulphur is withdrawn and cast into molds. The size and the form of this refining vessel depends to some extent upon the nature of the material to be treated. If the ore is porous, a higher vessel of greater capacity can be used, and with ores that increase their volume considerably from the action of the heat, the bottom of the vessel should be made of much larger cross section than the top, in order to facilitate the discharge of the spent ore after the sulphur has been extracted. The steam jets are so arranged that the melted sulphur can not accumulate at any point within the vessel except at the bottom. If properly arranged and operated the extraction of sulphur by means of superheated steam should be accomplished with the loss of not more than from 1.5 to 2 per cent of the quantity of sulphur treated.

Sulphur deposits of Italy.—Owing to the importance of the sulphur deposits of Italy, the following brief outline of the methods of mining and refining adopted in that country will be found of interest.[1]

In Sicily the sulphur mineral is disseminated through the matrix, sometimes in considerable masses of nearly pure sulphur, but usually in fine seams or grains. The methods of obtaining it are very crude and wasteful. The mines are for the most part open pits, ranging from 200 to 500 feet in depth, and the ore is carried to the surface in baskets or sacks by laborers, who ascend by inclined paths on the walls of the pit. In a few of the better mines, however, hoisting machinery is now used, but the introduction of this method has met with the determined opposition of the laborers.

The ore is generally refined in a very simple manner, the process being carried on in kilns called "calceroni." As usually constructed, these are shallow pits about 30 feet in diameter, with walls about 10 feet high, made tight with mortar. They are generally built on a hillside, and the sloping bottom is beaten smooth. The ore is arranged in the calcerone so as to leave a few vertical draft holes from top to bottom of the heap, which is fired by dropping burning brush or straw into these openings. The sulphur, which forms from 25 to 40 per cent of the ore, burns freely, and when the heap is well on fire the draft holes are closed, the calcerone covered with spent ore, and the whole left for several days. The heat given out by the burning of part of the sulphur is sufficient to melt the remainder from the gangue, and it collects in a pool near a tap hole made in the wall at the lowest point. At intervals of a few hours the melted sulphur is drawn off into molds. If the temperature rises above 180° C. (356° F.), there is a large formation of plastic sulphur, which will not flow from the tap hole. The time necessary to burn out a calcerone varies from thirty-five to eighty days, according to its size, the weather, and the nature of the impurities; for example, much gypsum retards the process, owing to the water it contains. Usually from a quarter to a third of the sulphur is lost as sulphur dioxide during the burning. As this causes much damage to vegetation in the vicinity, the burning of calceroni is prohibited during the spring and summer months.

[1] F. H. Thorp: Outlines of Industrial Chemistry, 1898.

PYRITE.

The name pyrite is derived from the Greek word πυρίτης meaning "of the nature of fire," and alludes to the property possessed by the mineral of producing sparks when struck with a hard substance. Specifically, the name pyrite is restricted to the isometric crystalline form of the native iron bisulphide mineral (FeS_2) containing 46.6 per cent of iron and 53.4 per cent of sulphur. The mineral marcasite is also a native iron bisulphide (FeS_2) of identically the same chemical composition as pyrite, but it occurs in crystals of the orthorhombic system of crystallization. In a general sense, pyrite includes that class of native minerals in the massive or crystalline form composed of a metallic sulphide or arsenide, or both. Iron, copper, nickel, and cobalt pyrites are the principal minerals of this class.

Occurrence.—Pyrite occurs abundantly in rocks of all geologic ages, from the oldest crystalline to the most recent alluvial deposits. In crystalline formation it usually occurs in small cubes, pyritohedrons, or in more highly modified shapes; also in irregular spheroidal nodules, and in the massive form in clay slate, argillaceous sandstone, coal formation, etc.

Uses.—Pyrite is used principally in the manufacture of sulphuric acid. Recently it has also been used in pyritic and allied smelting processes and, to some extent, in making sulphur dioxide gas for use in bleaching wood pulp. In vulcanizing rubber and in the preparation of medicinal compounds the use of pyrite is impracticable.

Deposits and mining in the United States.—The deposits of pyrite in the United States are quite numerous and widespread. The largest deposits so far discovered are at Mineral, Va., and Charlemont, Mass. Deposits are also found in Alabama, California, Georgia, Indiana, New York, and Ohio. The mineral was mined in these states in 1902. Virginia supplied nearly one-half of the total. The production in Indiana and Ohio was in the form known as "coal brasses," ob-

tained as a by-product in the mining of coal. The total quantity so produced, however, was but a small proportion of the total output of the United States. It is not probable that the production of pyrite from this source will ever become of importance.

There are many other deposits of pyrite in the United States, but they have not been exploited because of the impure or low-grade quality of the ore and the excessive cost of mining and of transportation both to and on the railroads leading to the centers of consumption. Some of the ores not now deemed of sufficient value to be worked for their sulphur content will eventually be profitably treated by modern methods. In the Southern states particularly are many deposits of this character, which could produce enormous amounts of sulphuric acid in this manner at prices lower than the present average prices at the seaboard. A condition which has served to retard the growth of the production of the domestic ore lies in the fact that foreign ores can be imported and accumulated at the seaboard and shipped inland in quantities sufficiently large to secure very low freight rates.

A promising prospect for the pyrrhotite ores of the South lies in the feasibility of their utilization for the manufacture of sulphuric acid. It is claimed that the sulphur contained in these ores can be so effectually removed that the residual product will be of value in the manufacture of pig iron or even of steel. For this purpose the cinders or residues from the roasting of pyrite for the manufacture of sulphuric acid have been utilized to advantage. It is well known that the residues from Spanish ores treated by the Henderson process have been sold either in the form of "fines" or "briquetting" and utilized in the manufacture of steel, but in the United States roasted pyrite residues have not yet been utilized for the manufacture of iron on account of the large percentage of sulphur remaining in them after treatment in the chemical works. If pyrite residues could be roasted so that the amount of sulphur remaining after treatment would be so small as to permit of their utilization for the manufacture of pig iron, there would result an annual saving of many thousand tons from what is now a waste product. As yet, however, the recovery of sulphur and iron from these ores is in an experimental state.

Other experiments have recently been conducted for the utilization of the by-product gases resulting from the roasting of zinc blende ores, the practicability of which has been demonstrated with financial profit at the zinc plants of Peru and Lasalle, in Illinois, and of Argentine, in Kansas. It is feasible to save from 25 to 28 per cent of the sulphur content of the zinc ores during the roasting, which yields a product containing not more than 2 per cent of sulphur. By subsequently roasting this product—cinders, as it is called—in the Chase or other type of special roasting furnace the remainder of the sulphur will be expelled, and the dead-roasted zinc ore will then be in proper condition to permit of the extraction of the zinc at very low cost. There is an immense supply of sulphur in the zinciferous sulphide ores of Arkansas, Colorado, Kansas, Kentucky, Missouri, and other states, and it is well within the range of probability that ere long the tonnage of sulphur derived from pyritiferous ores will be largely augmented by the utilization of the sulphur contained in these zinc sulphide ores.

An important factor in the development of the pyrite industry is the demand for sulphuric acid in the treatment of phosphate rock, and in the refining of petroleum. Since a chemically pure sulphuric acid is not essential for these purposes, the acid made from pyrites serves quite as well as that made from sulphur. Another field for the future extension of the utilization of the pyritiferous ores lies in the making of sulphur dioxide gas for use in bleaching wood pulp, which is the basis of the manufacture of paper by the sulphite process. Heretofore American manufacturers of paper using this process, with one or two exceptions, have been limited to the use of sulphur for making sulphur-dioxide gas, although in Europe a considerable quantity of pyrite has been thus utilized. It is quite probable that the difficulties that have heretofore existed in the way of utilizing pyrite in the bleaching of pulp will be overcome in the near future. When this becomes an accomplished fact it will open up a large field for the consumption of pyrite in New York state, and also of the lean cupriferous pyritic ores of the New England states. Where the conditions are favorable for deep mining and concentration and for shipment to the numerous paper mills of that section, constant and large supplies of sulphur will thus be guaranteed at prices much lower than can be expected from outside sources.

THE MANUFACTURE OF SULPHURIC ACID.

The manufacture of sulphuric acid is of great industrial importance, as the acid is of primary importance in the manufacture of phosphate rock fertilizers and in the refining of petroleum. It is also required in the manufacture of other acids and chemical salts, and has a very wide field in the making of alizarin dyes, artificial indigo, and many other important chemical salts. Of the immense quantities of sulphuric acid made yearly, the greater part does not appear on the market; because of the expense and difficulty of shipping it, consumers of large amounts generally make their own acid.

Until a few years ago the total quantity of ordinary sulphuric acid produced in the world had been obtained by burning crude sulphur in air, the resultant sulphur dioxide gas being then passed, together with

steam and an oxidizing agent, generally nitric oxide, into lead-lined chambers, where these gases react on one another and form the dilute acid, which is subsequently purified and concentrated to the desired degree of strength. This process is called the lead-chamber process, but a newer and more satisfactory process is the "contact" process, in which the sulphur dioxide gas, in the presence of so-called "catalytic" substances (platinum sponge, platinized asbestos, iron oxide, etc.) is directly oxidized to sulphur trioxide (SO_3), which is then absorbed in water to form sulphuric acid of any degree of strength. Recently it has been found more economical in making sulphuric acid to utilize the sulphide minerals as the source of sulphur dioxide gas. In this manner the more costly brimstone is reserved for purposes other than acid manufacture, and for which the sulphide minerals would not be applicable.

The use of pyrite as a raw material in the manufacture of sulphuric acid was first proposed by an Englishman named Hill, who obtained a patent for the process in 1818. It was not until 1838, however, when the price of crude sulphur was nearly trebled by the French firm who had purchased from the Sicilian government the monopoly of the sulphur exportation from that island, that the use of pyrite by acid makers attained any importance. In the United States, which leads the world in the consumption of sulphur, this substitution of pyrite for sulphur in acid making has continued steadily during the past twenty-five years, and owing to its cheapness and widespread occurrence, pyrite has almost completely replaced the crude sulphur that was formerly used almost exclusively. This change in acid making has resulted largely from the treatment of phosphate rock by sulphuric acid, by which it is made into valuable fertilizer, and also from the use of the acid in the refining of crude petroleum. For these purposes the use of a high-grade, pure sulphuric acid is not essential. Unrefined sulphuric acid made from pyrite is generally contaminated with arsenic, and frequently with the additional impurities, copper, zinc, and selenium, but not in sufficient quantities to bar its use in preparing fertilizers or in refining the crude petroleum. The impurities, too, may be removed if desired, and a pure acid produced.

To give some idea of the large quantities of the acid consumed in these industries, it may be stated that 1 pound of acid of chamber strength is required to convert each pound of crude phosphate rock into acid phosphate or commercial fertilizer, and during 1902 over 1,500,000 long tons of the crude phosphate rock were mined. In refining crude petroleum each gallon of commercial petroleum (kerosene) requires 1 pound of sulphuric acid of a strength of 66° B. for its production, and during 1902 the output of crude petroleum in the United States amounted to over 89,000,000 barrels, each of 42 gallons capacity. In estimating the quantity of acid consumed in these two industries alone, any calculation based upon figures of production, less imports, both of crude petroleum and phosphate rock, must necessarily be tentative and not even closely approximate, for the reason that it is impracticable to ascertain the exact quantities of stock of crude material on hand at the beginning and at the close of a year. For practical purposes, however, it may be assumed that the consumption of sulphuric acid in the United States at the present time is approximately in the following proportions: For the treatment of phosphate rock, 50 per cent; for refining crude petroleum, 38 per cent; and for use in the chemical trade, 12 per cent.

In making sulphuric acid from pyrite, pieces of the mineral ranging in size from several inches in circumference to extreme fineness are burned with access of air in a furnace, of which there are many forms, each suited for some special physical or chemical characteristic of the ore. As a result of the burning, or oxidation, the sulphur content of the pyrite or pyritiferous ore is converted into sulphur dioxide gas. When the ore contains over 30 per cent of sulphur, the heat generated by the oxidation of the sulphur is sufficient to maintain combustion without fuel. The sulphur dioxide gas produced in this manner is purified, and subsequently converted into sulphuric acid, either by the chamber process, in which the oxidation is accomplished by nitric oxide gases and steam, or by the contact process, previously described.

TABLE 6.—DETAILED SUMMARY: 1902.

	United States.	Virginia.	All other states.[1]
Number of mines	23	6	17
Number of operators	18	4	14
Character of ownership:			
Individual	1	1	.....
Firm	3	1	2
Incorporated company	14	2	12
Salaried officials, clerks, etc.:			
Total number	54	32	22
Total salaries	$49,890	$29,970	$19,920
General officers—			
Number	6	4	2
Salaries	$9,050	$7,450	$1,600
Superintendents, managers, foremen, surveyors, etc.—			
Number	31	17	14
Salaries	$28,582	$13,952	$14,630
Foremen below ground—			
Number	7	3	4
Salaries	$5,390	$3,200	$2,190
Clerks—			
Number	10	8	2
Salaries	$6,868	$5,368	$1,500
Wage-earners:			
Aggregate average number	970	655	315
Aggregate wages	$398,870	$222,986	$175,884
Above ground—			
Total average number	541	389	152
Total wages	$199,315	$122,431	$76,884
Engineers, firemen, and other mechanics—			
Average number	126	105	21
Wages	$57,957	$45,037	$12,920
Miners—			
Average number	28	.....	28
Wages	$14,196	.....	$14,196
Boys under 16 years—			
Average number	13	13	.....
Wages	$2,017	$2,017	.....
All other wage-earners—			
Average number	374	271	103
Wages	$125,145	$75,377	$49,768
Below ground—			
Total average number	429	266	163
Total wages	$199,555	$100,555	$99,000
Miners—			
Average number	273	206	67
Wages	$122,874	$78,964	$43,910
Miners' helpers—			
Average number	108	56	52
Wages	$55,766	$20,216	$35,550
All other wage-earners[2]—			
Average number	48	4	44
Wages	$20,915	$1,375	$19,540
Average number of wage-earners at specified daily rates of pay:			
Engineers—			
$1.00 to $1.24	1	1	.....
$1.25 to $1.49	7	7	.....
$1.50 to $1.74	7	6	1
$1.75 to $1.99	6	2	4
$2.00 to $2.24	5	4	1
$2.25 to $2.49	1	.....	1
$2.50 to $2.74	2	1	1
Firemen—			
$1.00 to $1.24	6	6	.....
$1.25 to $1.49	11	9	2
$1.75 to $1.99	1	1	.....
$2.00 to $2.24	2	1	1
$2.25 to $2.49	2	.....	2
Machinists, blacksmiths, carpenters, and other mechanics—			
$1.00 to $1.24	23	23	.....
$1.25 to $1.49	23	23	.....
$1.50 to $1.74	12	9	3
$1.75 to $1.99	5	4	1
$2.00 to $2.24	6	6	.....
$2.50 to $2.74	5	2	3
$3.00 to $3.24	1	.....	1
Miners—			
$1.00 to $1.24	33	33	.....
$1.25 to $1.49	110	103	7
$1.50 to $1.74	88	60	28
$1.75 to $1.99	5	5	.....
$2.00 to $2.24	43	4	39
$2.50 to $2.74	16	1	15
$3.00 to $3.24	6	.....	6
Average number of wage-earners at specified daily rates of pay—Continued.			
Miners' helpers—			
$1.00 to $1.24	30	30	.....
$1.25 to $1.49	25	25	.....
$1.50 to $1.74	6	1	5
$1.75 to $1.99	12	.....	12
$2.50 to $2.74	35	.....	35
Timbermen and track layers—			
$1.50 to $1.74	1	1	.....
$1.75 to $1.99	16	.....	16
Boys under 16 years—			
Less than $0.50	5	5	.....
$0.50 to $0.74	7	7	.....
$0.75 to $0.99	1	1	.....
All other wage-earners—			
Less than $0.50	10	10	.....
$0.50 to $0.74	45	45	.....
$0.75 to $0.99	49	49	.....
$1.00 to $1.24	195	162	33
$1.25 to $1.49	29	4	25
$1.50 to $1.74	55	3	52
$2.00 to $2.24	11	1	10
$2.25 to $2.49	11	.....	11
Average number of wage-earners employed during each month:			
Men 16 years and over—			
January	947	659	288
February	945	663	282
March	965	673	292
April	964	643	321
May	992	657	335
June	1,032	686	346
July	1,041	730	311
August	1,004	673	331
September	959	620	339
October	928	599	329
November	900	583	317
December	807	518	289
Boys under 16 years—			
January	8	8	.....
February	8	8	.....
March	10	10	.....
April	16	16	.....
May	17	17	.....
June	18	18	.....
July	18	18	.....
August	16	16	.....
September	11	11	.....
October	12	12	.....
November	10	10	.....
December	12	12	.....
Contract work:			
Amount paid	$3,587	$1,134	$2,453
Number of employees	15	4	11
Miscellaneous expenses:			
Total	$39,118	$23,285	$15,833
Royalties, and rent of mine and mining plant	$7,048	.....	$7,048
Rent of offices, taxes, insurance, interest, and other sundries	$32,070	$23,285	$8,785
Cost of supplies and materials	$217,262	$137,491	$79,771
Product:			
Quantity, long tons	207,874	127,642	80,232
Value	$947,089	$501,642	$445,447
Power:			
Total horsepower	6,305	1,400	4,905
Owned—			
Engines—			
Steam—			
Number	32	22	10
Horsepower	5,915	1,160	4,755
Gas or gasoline—			
Number	1	.....	1
Horsepower	20	.....	20
Other power—			
Number	4	3	1
Horsepower	320	240	80
Rented—			
Horsepower	50	.....	50
Electric motors, owned—			
Number	2	2	.....
Horsepower	80	80	.....

[1] Includes operators distributed as follows: Alabama, 1; California, 2; Georgia, 1; Louisiana, 1; Massachusetts, 1; Missouri, 2; Nevada, 1; New York, 1; Ohio, 3 (6 mines); Utah, 1.

[2] Includes timbermen and track layers.

BARYTES

BARYTES.

By Joseph Hyde Pratt.

The mining of barytes has been carried on in the United States for about fifty years, but it is still an industry of minor importance. Barytes was first produced in small quantities for use as an adulterant of white lead. Statistics of production for 1902 are presented in Table 1, with such facts as are available for the censuses of 1860, 1870, 1880, and 1890.

Table 1.—*Production of barytes: 1860 to 1902.*

Census.	Quantity (short tons).	Value.	Where produced.
1860	.....	$25,000	New York.
1870	.....	100,000	Connecticut.
1880	3,608	37,491	Georgia, Missouri, Pennsylvania, Virginia.
1890 (for calendar year 1889).	21,460	106,313	Missouri, Virginia, Illinois.
1902	61,668	203,154	Missouri, North Carolina, Tennessee, Virginia.

At the census of 1860 the statistics of this mining industry were not separately reported, but were included among those for manufactures. Returns were given for 1 barytes establishment in Westchester county, N. Y., which had 40 employees, who received $12,000 in wages. The cost of materials was given as $5,000, and the value of product as $25,000.

The only statistics reported for this industry at the census of 1870 were those of 1 establishment in New Haven county, Conn., which employed 110 men, all above ground, to whom $78,000 was paid in wages. The cost of materials was $5,518, the capital $50,000, and the value of the product (quantity not stated) $100,000. The deposit, which was located at Cheshire, had been mined quite extensively, as is shown by the old workings.

At the census of 1880 the statistics for barytes were shown under minor minerals, and a total of 6 mines was reported for the states of Georgia, Missouri, Pennsylvania, and Virginia. These employed 63 wage-earners, to whom was paid $7,802 in wages. The cost of materials was given as only $200, making the total cost $8,002 for the production of 3,608 tons, which was valued at $37,491. This is an increase of $12,491 in the value of the production of 1880 over that of 1860.

At the Eleventh Census mining industries were shown separately, and included barytes. The statistics, however, for this mineral were not uniform for the whole country, and are not, therefore, comparable with those for 1902.[1]

The quantity of barytes produced in 1889 was given as 21,460 short tons, valued at $106,313, an increase of 17,852 tons in quantity, and of $68,822 in value, over that for the year 1880. Most of this production was obtained from Missouri and Virginia, with a smaller amount from Illinois.

At the census for the calendar year 1902, the quantity of barytes produced was given as 61,668 short tons, valued at $203,154, which is an increase of 40,208 short tons in quantity and of $96,841 in value, over the production reported at the census of 1890.

In 1902 no product of barytes was reported for New York, Connecticut, Georgia, and Illinois, although these states were returned as producers at one or all of the censuses of 1860, 1880, and 1890.

[1] Barytes mining in Missouri is carried on in such a very irregular manner that it is impossible to obtain any reliable statistics relative to labor and wages. Farmers mine it in off seasons; that is, when there is no farming to do they employ themselves and their hands in getting out the barytes found on their farms, haul it to the nearest tradesman, and receive in exchange dry goods, groceries, or other necessaries, or cash. The farmers thus occupy time which would otherwise be idle, and dispose of the barytes at a less figure than it would pay to mine it systematically. The supply thus obtained is nearly sufficient to keep the mills up to their fullest capacity.

A few mines are, however, operated with some degree of system, though for want of proper records it is necessary to estimate a considerable portion of the matter of labor and wages. The mines altogether give irregular employment to about 580 men. The rate of compensation for foremen is about $2.50 per day, and for laborers from $1 to $1.50 per day. It is rarely, however, that the men make full time, and their daily earnings are reported at from 50 to 75 cents. From 75 to 100 women obtain the same sort of irregular employment, earning about 35 cents per day. Boys get from 25 to 30 cents per day. One mine was active nearly the entire year, but in most cases the number of days worked at the mines ranged from 125 to 200. One mine in Illinois employed 10 men and 2 women for 52 days. (Eleventh Census, Mineral Industries, page 745.)

The large increase in the use of white lead is one of the principal reasons for the increase in the production of barytes. This mineral was formerly considered simply as an adulterant, but it is now beginning to be recognized that it has qualities of its own that make it of value as a pigment, and when it is used in combination with white lead or zinc white, these qualities appear to advantage.

Table 2 is a summary of the statistics for 1902.

TABLE 2.—*Summary: 1902.*

Number of mines or quarries	49
Number of operators	42
Salaried officials, clerks, etc.:	
Number	28
Salaries	$15,159
Wage-earners:	
Average number	336
Wages	$130,285
Contract work	$1,000
Miscellaneous expenses	$35,555
Cost of supplies and materials	$7,772
Product:[1]	
Quantity, short tons	61,668
Value	$203,151

[1] Includes 539 tons, valued at $1,618, the product of two lead mines; the wages and other details are embraced in the statistics for lead.

Of the 49 mines or quarries shown for 1902, 34 are in Missouri, 5 in North Carolina, 6 in Tennessee, and 4 in Virginia. These were controlled by 42 operators, of whom 16 were individuals, 20 firms, and 6 incorporated companies. Each of 2 firms operated 4 mines. Missouri leads in this industry, with 69.4 per cent of the mines and 51.5 per cent of the value of the production. North Carolina is next in respect to the value, with 21.7 per cent, and Virginia third, with 19.5 per cent. Tennessee produced only 7.2 per cent of the total value of the production, although reporting 6 mines, which is 1 more than North Carolina and 2 more than Virginia.

Six mines or quarries were idle during the year, 1 each in Missouri and Ohio, and 2 each in Tennessee and Virginia.

Capital stock of incorporated companies.—Table 3 shows the capitalization and bonded indebtedness of the 6 incorporated companies.

TABLE 3.—*Capitalization of incorporated companies: 1902.*

Number of incorporated companies	6
Capital stock and bonds issued	$1,158,900
Capital stock (all common):	
Total authorized—	
Number of shares	115,050
Par value	$10,983,000
Total issued—	
Number of shares	15,019
Par value	$979,900
Dividends paid	$2,640
Bonds:	
Authorized—	
Number	1,700
Par value	$1,700,000
Issued—	
Number	179
Par value	$179,000
Interest paid	$6,000

Two of these companies were operating in Missouri, 2 in North Carolina, and 2 in Virginia. The entire stock, both authorized and issued, is common stock. A little more than 8.9 per cent, par value, of the authorized stock has been issued and a little more than 10.5, par value, of the bonds. Dividends of $2,640 were paid on $58,000 of the $979,900 capital stock issued.

Employees and wages.—There were at the 49 mines or quarries a total average number of 364 employees, of whom 28, or 7.7 per cent, were classified as salaried employees, and 336, or 92.3 per cent, as wage-earners. Of the total amount, $145,444 reported as paid for salaries and wages by the 42 operators engaged in the production of barytes, $130,285, or 89.6 per cent, was paid to the wage-earners and $15,159, or 10.4 per cent, to the salaried employees. The classification of these 364 salaried employees and wage-earners is shown in Table 6.

Of the 321 wage-earners classified as miners or quarrymen, only 51, or 15.9 per cent, were employed below ground, of which 31 were in North Carolina, 16 in Virginia, and only 4 in Missouri, although the latter state produces over one-half of the total production. This is due to the entirely different occurrence of the deposits of barytes in North Carolina and Virginia as compared with those in Missouri. In the latter state the deposits occur near the surface, so that they can be worked almost entirely by means of pits and open cuts, while those in Virginia and North Carolina have to be worked largely by means of shafts, tunnels, and drifts. There was obtained from those mines reporting wage-earners below ground a production of barytes valued at $62,900, or 31 per cent of the total value. The total underground wage-earners numbered 52, or 15.5 per cent of the total wage-earners, and their wages constituted 12.1 per cent of the total wages paid. The 8 wage-earners shown under "all other wage-earners" are laborers who handle, load, and haul the ore and do miscellaneous work.

There were on an average 7 wage-earners to a mine or quarry. In addition to the number of regularly employed wage-earners, 10 were employed in contract work in North Carolina at an expense of $1,000. They worked altogether a total of one hundred days.

The number of wage-earners employed during each month, and their daily rates of pay, are shown in Table 6. The busiest month of the year for the industry as a whole was the month of May, when a total of 443 wage-earners were at work. August was the next busiest month, with 441. The least active month was December, with 144. Many of the companies in Missouri employ no regular miners, the work being done by the farmers of the neighborhood who work in the mines at odd times. The company pays them for the ore dug, whether it comes in small or large quantities, or whether by bucket, sack, barrel, or wagon load. Of the total number of wage-earners 321, or 95.5 per cent, are classed as miners. Of this number the wages of 135, or 42.1 per cent, ranged from $1 to $1.24 per day, and those of 66, or 20.6 per cent, ranged from $1.75 to

$1.99 per day. The miner who received from $0.50 to $0.74 a day was employed in Virginia. The prevailing wages for all classes of wage-earners was from $1 to $1.24 a day, there being 143, or 42.6 per cent, paid at this rate.

Supplies, materials, and miscellaneous expenses.—The amount expended for supplies and materials was $7,772. Of the miscellaneous expenses, amounting to $35,555, $27,300, or 76.8 per cent, was expended for royalties and rent of mines and mining plant, the remainder being for rent of offices, taxes, insurance, interest, and other sundries.

Mechanical power.—Of the 42 operators from whom returns were received only 2 reported that power was required for the operation of their mines. These were in North Carolina and Virginia. The total horsepower amounted to 110, furnished by 3 steam engines.

Production.—The total production of barytes for the calendar year 1902 was 61,668 short tons, valued at $203,154, of which Missouri produced 31,334 short tons, or 50.8 per cent of the total; North Carolina, 14,679 short tons, or 23.8 per cent; Tennessee, 3,255 short tons, or 5.3 per cent; and Virginia, 12,400 short tons, or 20.1 per cent. A comparison of the production for this industry since 1889 is shown in the following table, which gives the statistics relating to the quantity and value of barytes, as published by the United States Geological Survey:

TABLE 4.—*Production of barytes: 1889 to 1902.*

[United States Geological Survey, "Mineral Resources of the United States," 1902.]

YEAR.	Quantity (short tons).	Value.	Average value per ton.
1889	21,460	[1] $106,313	$4.95
1890	21,911	86,505	3.95
1891	31,069	118,363	3.81
1892	32,108	130,025	4.05
1893	28,970	88,506	3.06
1894	23,335	86,983	3.73
1895	21,529	68,321	3.17
1896	17,068	46,513	2.73
1897	26,042	58,295	2.23
1898	31,306	108,339	3.50
1899	41,894	139,528	3.33
1900	67,680	188,089	2.78
1901	49,070	157,844	3.22
1902	61,668	203,154	3.29

[1] Value includes floated barytes when sold first in that form.

As shown by the above table, there was an increase of 12,598 tons in quantity and of $45,310 in value in the production of 1902 over that of 1901. Of the 1902 production 539 tons, valued at $1,618, were obtained as a by-product from 2 lead mines; and the salaries, wages, and other expenses of these mines are credited to the lead industry.

The largest production reported for this industry was in 1900, when it amounted to 67,680 short tons. In value, however, 1902 leads with a valuation of $203,154, while that of 1900 was $188,089. This is due to the higher average price received per ton for the barytes in 1902, which was $3.29, or 51 cents more than the average price of $2.78 per ton received in 1900. The total quantity of barytes produced in the United States since 1882 is 622,950 short tons, an average production of 29,664 tons per year.

The highest average value reported in the table for any year was $4.95 in 1889, and the lowest $2.23 in 1897. In 1902 the price per ton reported varied from $1.65 to $4.50, but the average was $3.29 per ton.

In 1902, there were imported barytes, manufactured and unmanufactured, to the value of $51,711, and other barium compounds, nearly all of which could be made of domestic barytes, to the value of $152,361. The imports of barytes from 1889 to 1902, inclusive, as published by the United States Geological Survey, are shown in the following table:

TABLE 5.—*Imports of barytes: 1889 to 1902.*

[United States Geological Survey, "Mineral Resources of the United States," 1902.]

YEAR ENDING DECEMBER 31—	MANUFACTURED.		UNMANUFACTURED.	
	Quantity (short tons).	Value.	Quantity (short tons).	Value.
1889	1,801	$22,458	6,785	$7,660
1890	1,563	16,453	4,815	13,133
1891	2,149	22,041	2,900	8,816
1892	1,389	15,419	2,789	7,418
1893	1,032	11,457	2,983	7,612
1894	836	10,556	1,884	5,270
1895	1,629	17,112	2,551	7,561
1896	2,467	23,345	509	1,274
1897	1,300	13,822	502	579
1898	687	8,678	1,022	2,678
1899	2,111	22,919	1,739	5,488
1900	2,454	24,160	2,568	8,301
1901	2,454	27,062	3,160	12,380
1902	3,908	37,389	3,929	14,322

Table 6 is a detailed summary of the statistics of the barytes industry for 1902.

DESCRIPTIVE.

The first mining for barytes in the United States was very probably in Westchester county, N. Y., prior to 1860, and this was followed in the next decade, 1860 to 1870, by the opening of the mine at Cheshire, New Haven county, Conn. Between 1870 and 1880 barytes deposits had been opened in Georgia, Missouri, Pennsylvania, and Virginia, while those of New York and Connecticut had ceased to be producers. Between 1880 and 1890 Illinois had been added to the states producing this mineral, and during the next decade, from 1890 to 1900, North Carolina and Tennessee became producers, and in 1902 deposits of this mineral began to be developed in Kentucky. This makes a total of 9 states in which this mineral has been found in commercial quantity. In 1902 Missouri, North Carolina, Tennessee, and Virginia were producers of this mineral, with known deposits in Illinois and Kentucky, which are being developed, with the expectation of putting their product on the market in 1903. The Missouri deposits are fur-

nishing more than one-half of the barytes mined in the United States. They are located in Cole, Crawford, Miller, St. Francois, and Washington counties, with by far the larger proportion of the mines in the last-named county. There are a number of deposits in these five counties that probably contain barytes in quantity, but on account of their distance from the railroad they are not mined to any great extent at the present time. The mineral is found for the most part associated with limestone. This rock is often altered and decomposed to some depth, leaving a residual clay-like material in which the barytes, which has resisted the alteration, is found. Sometimes the barytes is encountered close under the grass roots. The lead ore, galena, is associated more or less with the barytes, and it makes a very valuable by-product, although occasionally a deposit is found that is practically free from this mineral. Where the barytes is encountered near the surface in the clay, it is apt to be stained more or less with iron oxide.

In North Carolina the barytes deposits occur in Gaston, Madison, and Orange counties, those which were worked most extensively during 1902 being in Madison county. The mining in this state is largely by means of shafts, tunnels, and drifts.

The Tennessee barytes deposits are located in Bradley, Cocke, Greene, Loudon, and Monroe counties, but during 1902 the production of this mineral was much less than the year before. The erection, however, of a large barytes mill for grinding this mineral and preparing it for market, and also for the production of artificial sulphate of barium, and other compounds of barium, will undoubtedly lead to a considerable increase of the industry in this state.

In Virginia the barytes mines are located in Bedford, Campbell, Louisa, Pittsylvania, Russell, and Tazewell counties. The mines near Evington, Campbell county, where the mining is now carried on largely by means of shafts and drifts, have been worked almost continuously since 1874. About 1901 the deposits of Russell and Tazewell counties were opened, and the latter gives prospect of becoming the largest producer of this mineral in Virginia.

The deposits of barytes that are being developed in Illinois are in Hardin county, and those of Kentucky are in Crittenden county.

The growth of this industry has been partially dependent on the growth of the paint industry, in which a very large proportion of the barytes produced is used. The barytes has a pure white color, which is permanent, and it is unaffected by weather or by gases that in some instances blacken white lead, for which the barytes is used as a substitute. Besides the use of barytes in the paint industry, it is employed in the manufacture of paper and rope to give weight; and also in the preparation of a material that is used to coat the canvas sacks in which hams are wrapped when ready for market. Another use for this mineral, and one that should increase rapidly, is in the manufacture of other barium compounds, principally the hydroxide. This compound was formerly prepared almost exclusively from the mineral witherite, barium carbonate; but on account of its rare occurrence in commercial quantity, barytes has begun to be the raw material used in the manufacture of this hydroxide and other salts of barium. One of the greatest uses of the barium hydroxide will perhaps be in the beet sugar industry, for the separation of the sugar left in the molasses. It is also claimed that the compound is applicable in the cane sugar industry. Other uses considered for it are in the purifying of water used in steam boilers and in the preparation of hides for tanning. As these uses of barium hydroxide increase there should be a larger demand, and consequently a larger production of barytes.

These multiplying uses for barytes put the industry on a new basis, and take the mineral out of the list of adulterants with which it has been usually classified.

TABLE 6.—DETAILED SUMMARY: 1902.

	United States.	Missouri.	North Carolina.	Tennessee.	Virginia.
Number of mines or quarries	49	34	5	6	4
Number of operators	42	28	5	6	3
Character of ownership:					
Individual	16	10	.....	5	1
Firm	20	16	3	1	.....
Incorporated company	6	2	2	.....	2
Salaried officials, clerks, etc.:					
Total number	28	4	13	1	10
Total salaries	$15,159	$670	$5,401	$1,000	$8,088
General officers—					
Number	8	2	1	.....	5
Salaries	$5,308	$300	$1,000	.....	$4,008
Superintendents, managers, foremen, surveyors, etc.—					
Number	7	1	2	1	3
Salaries	$5,570	$70	$1,500	$1,000	$3,000
Foremen, below ground—					
Number	9	.....	8	.....	1
Salaries	$3,001	.....	$2,401	.....	$600
Clerks—					
Number	4	1	2	.....	1
Salaries	$1,280	$300	$500	.....	$480
Wage-earners:					
Aggregate average number	336	239	34	26	37
Aggregate wages	$130,285	$99,799	$9,914	$7,525	$13,047
Above ground—					
Total average number	284	235	2	26	21
Total wages	$114,551	$98,529	$450	$7,525	$8,047
Engineers, firemen, and other mechanics—					
Average number	4	.....	2	1	1
Wages	$1,650	.....	$450	$600	$600
Miners or quarrymen—					
Average number	270	235	.....	23	12
Wages	$110,086	$98,529	.....	$6,625	$4,932
Boys under 16 years—					
Average number	2	.....	.....	2	.....
Wages	$300	.....	.....	$300	.....
All other wage-earners—					
Average number	8	.....	.....	.....	8
Wages	$2,515	.....	.....	.....	$2,515
Below ground—					
Total average number	52	4	32	.....	16
Total wages	$15,734	$1,270	$9,464	.....	$5,000
Miners—					
Average number	51	4	31	.....	16
Wages	$15,446	$1,270	$9,176	.....	$5,000
Miners' helpers—					
Average number	1	.....	1	.....	.....
Wages	$288	.....	$288	.....	.....
Average number of wage-earners at specified daily rates of pay:					
Engineers—					
$2.00 to $2.24	2	.....	.....	1	1
Firemen—					
$0.75 to $0.99	2	.....	2	.....	.....
Average number of wage-earners at specified daily rates of pay—Cont'd.					
Miners or quarrymen—					
$0.50 to $0.74	1	.....	.....	.....	1
$0.75 to $0.99	15	2	3	10	.....
$1.00 to $1.24	135	80	28	10	17
$1.25 to $1.49	30	17	.....	3	10
$1.50 to $1.74	74	74	.....	.....	.....
$1.75 to $1.99	66	66	.....	.....	.....
Miners' helpers—					
$0.75 to $0.99	1	.....	1	.....	.....
Boys under 16 years—					
$0.50 to $0.74	2	.....	.....	2	.....
All other wage-earners—					
$1.00 to $1.24	8	.....	.....	.....	8
Average number of wage-earners employed during each month:					
Men 16 years and over—					
January	244	160	44	23	17
February	402	308	42	35	17
March	414	332	42	23	17
April	418	326	44	23	25
May	443	334	43	23	43
June	426	329	31	23	43
July	427	324	27	33	43
August	437	319	27	33	58
September	306	200	27	33	46
October	194	104	27	17	46
November	153	69	27	11	46
December	144	63	27	11	43
Boys under 16 years—					
January	4	.....	.....	4	.....
February	4	.....	.....	4	.....
June	4	.....	.....	4	.....
July	4	.....	.....	4	.....
August	4	.....	.....	4	.....
September	4	.....	.....	4	.....
Contract work:					
Amount paid	$1,000	.....	$1,000	.....	.....
Number of employees	10	.....	10	.....	.....
Miscellaneous expenses:					
Total	$35,555	$18,951	$5,886	$475	$10,243
Royalties and rent of mine and mining plant	$27,300	$11,515	$5,680	$455	$9,650
Rent of offices, taxes, insurance, interest, and other sundries	$8,255	$7,436	$206	$20	$593
Cost of supplies and materials	$7,772	$2,405	$2,740	$540	$2,087
Product:					
Quantity, short tons	61,668	31,334	14,679	3,255	12,400
Value	$203,154	$104,677	$44,130	$14,647	$39,700
Power owned:					
Total horsepower	110	.....	100	.....	10
Engines—					
Steam—					
Number	3	.....	2	.....	1
Horsepower	110	.....	100	.....	10

MINERAL PIGMENTS, CRUDE

MINERAL PIGMENTS, CRUDE.

By JOSEPH STRUTHERS, Ph. D.

As early as 1850 the census statistics of ocher, which is a subclassification of crude mineral pigments, appeared among statistics of manufactures. There were only 2 establishments, and they were in Vermont. In 1860, 1 establishment was shown, also among manufacturing statistics, in Berkshire county, Mass. A census of mining industries was taken at the census of 1870, and ocher was included among stone quarrying industries. There were 4 establishments, all in Bennington county, Vt. Among the mining industries at the census of 1880, 7 establishments were given—1 in New Jersey and 3 each in Vermont and Virginia—but, according to a footnote, there were a few ocher mines in Virginia or West Virginia from which no returns were received.

At the Eleventh Census statistics were given among mineral industries for ocher and metallic paint. The number of establishments was not stated. The states of Alabama, Colorado, Georgia, Maryland, Massachusetts, Pennsylvania, Vermont, Virginia, and Wisconsin were shown for ocher, and Alabama, Colorado, New York, Ohio, Pennsylvania, Tennessee, and Wisconsin for metallic paints. The statistics were for the year 1889 and apparently included statistics of the manufacture of ores into marketable paints.

The substances included in this report, under the title "Mineral pigments, crude," are: Iron ores, hematite, or red iron ore (Fe_2O_3), and limonite of brown iron ore (Fe_2O_3, $3H_2O$); clay and other earths, comprising ocher (yellow, gray, and brown) umber (including Spanish brown), and sienna; soapstone, slate, and shale, utilized for making certain shades of gray pigment; and gypsum, or mineral white, used as a pigment for printing wall paper.

Table 1 presents comparative statistics for the industry for 1902, 1889, 1880, and 1870.

TABLE 1.—*Comparative summary: 1870 to 1902.*

	1902	1889[1]	1880[2]	1870[2]
Number of mines or quarries	35	(3)	7	(3)
Number of operators	35	(3)	(3)	4
Salaried officials, clerks, etc.:				
Number	63	8	(3)	(3)
Salaries	$53,593	$5,540	(3)	(3)
Wage-earners:				
Average number	256	387	100	12
Wages	$106,087	$129,515	$24,396	$5,600
Contract work	.....	$8,674	(3)	(3)
Miscellaneous expenses	$24,893	$21,796	(3)	(3)
Cost of supplies and materials	$58,073	$84,509	$1,890	$1,980
Product:[4]				
Quantity, short tons	35,479	36,184	4,037	(3)
Value	$360,885	$463,766	$135,840	$15,000

[1] Ocher and metallic paint only.
[2] Ocher only.
[3] Not reported.
[4] The United States Geological Survey reports 73,049 short tons of mineral paints, manufactured and sold, valued at $944,332. Census figures are for the crude mineral pigments.

The 35 mines reported for this industry in 1902 were controlled by 22 incorporated companies, 8 individuals, and 5 firms. The state of Pennsylvania led in production, having 58.6 per cent of the total quantity and 68.3 per cent of the total value; the state of Georgia was next, with 16 per cent of the quantity and 13.4 per cent of the value; Maryland had 7.1 per cent and 3 per cent, respectively; New York reported 3.6 per cent of the quantity and 1.2 per cent of the value, leaving for all other states 14.7 per cent and 14.1 per cent, respectively.

There were 13 mines reported idle during 1902, controlled by 6 incorporated companies, 4 firms, and 3 individuals. The 6 incorporated companies issued capital stock and bonds to the par value of $86,750, the total amount authorized being $96,750. Three of the mines were in California, 2 each in Georgia and Missouri, and 1 each in Alabama, Michigan, Ohio, Pennsylvania, Tennessee, and Vermont. From these 13 mines miscellaneous expenses to the amount of $36 were reported. The total horsepower of the engines at these idle mines was

given as 115—3 steam engines having a total of 95 horsepower and 1 water wheel with 20 horsepower.

Capital stock of incorporated companies.—The details of capital stock and funded debt are shown in the following table for 17 of the 22 incorporated companies controlling active mines. The figures for the remaining 5 companies are omitted because mining is but a small part of the total business of each.

TABLE 2.—*Capitalization of incorporated companies: 1902.*

	United States.	Georgia.	Pennsylvania.	All other states.
Number of incorporated companies	22	4	10	[1]8
Number reporting capitalization	17	3	10	[2]4
Capital stock and bonds issued	$946,700	$156,100	$650,600	$140,000
Capital stock:				
Total authorized—				
Number of shares	76,316	52,200	22,566	1,550
Par value	$1,400,300	$170,000	$1,075,300	$155,000
Total issued—				
Number of shares	67,361	51,492	14,469	1,400
Par value	$881,700	$126,100	$615,600	$140,000
Dividends paid	$11,439	.....	$9,939	$1,500
Common—				
Authorized—				
Number of shares	74,916	52,200	21,166	1,550
Par value	$1,310,300	$170,000	$985,300	$155,000
Issued—				
Number of shares	66,058	51,492	13,166	1,400
Par value	$801,400	$126,100	$535,300	$140,000
Dividends paid	$10,239	.....	$8,739	$1,500
Preferred—				
Authorized—				
Number of shares	1,400	.....	1,400	.....
Par value	$90,000	.....	$90,000	.....
Issued—				
Number of shares	1,303	.....	1,303	.....
Par value	$80,300	.....	$80,300	.....
Dividends paid	$1,200	.....	$1,200	.....
Bonds:				
Authorized—				
Number	30,100	30,000	100	.....
Par value	$65,000	$30,000	$35,000	.....
Issued—				
Number	30,100	30,000	100	.....
Par value	$65,000	$30,000	$35,000	.....
Interest paid	$2,850	$1,500	$1,350	.....

[1] Includes companies distributed as follows: Arkansas, 1; California, 1; Missouri, 2; New York, 2; Virginia, 1; Wisconsin, 1.
[2] Includes companies distributed as follows: Arkansas, 1; Missouri, 2; New York, 1.

Ten of the incorporated companies were in Pennsylvania, 4 in Georgia, 2 each in Missouri and New York, 1 each in Arkansas, California, Virginia, and Wisconsin. The capital stock and funded debt of the Pennsylvania companies was 68.7 per cent of the total. The par value of the capital stock issued by all the companies was 63 per cent of the total par value authorized. The bonded indebtedness was 6.9 per cent of the capital stock and funded debt. The dividends paid amounted to 1.3 per cent of the total stock issued and 3.4 per cent of the total stock on which they were declared. Eighty-nine and five-tenths per cent of the total amount paid in dividends was declared on common stock and 10.5 per cent on preferred. Of the total dividends, 86.9 per cent was paid on the stock of the Pennsylvania mines and 13.1 per cent on the stock of the mines of "all other states."

Employees and wages.—The wage-earners were 80.3 per cent of the salaried employees and wage-earners, and their wages were 66.4 per cent of the total salaries and wages. There were 7.3 wage-earners to a mine. Of all the states, Pennsylvania had by far the largest number of wage-earners, leading with 57.8 per cent of the total number and 63.2 per cent of the total wages paid. Georgia was next with 25.4 per cent of the wage-earners and 18.4 per cent of the wages paid, the remainder being divided between Maryland, New York, and "all other states." Of the total number of wage-earners in all the mines, 20.3 per cent were underground. Pennsylvania had 78.8 per cent of these underground workers and Georgia the remainder, or 21.2 per cent.

The average number of wage-earners employed during each month and their daily rates of pay by occupations are shown in Table 3. The number varied little the year through. The busiest months were apparently September and October, and the least busy, February and March.

No particular skill or experience is required on the part of a miner in this industry, therefore the rates of pay should not be compared with those reported for miners where greater skill is necessary. The mines are worked by open pits, shafts, or tunnels, and in some cases the ore is ground, floated, dried, or otherwise prepared for market at the mines. Of the total number of wage-earners, 90, or 35.2 per cent, are classed as miners or quarrymen, and 102 as "all other wage-earners." Of the 90 miners, 24 received from $1.50 to $1.74 per day; 23 from $1.25 to $1.49; and 21 from $0.75 to $0.99. Of the "all other wage-earners" reported, 32 received from $1 to $1.24 per day and 31 from $1.50 to $1.74. These men are employed doing miscellaneous work around the quarries, sorting the ore, washing and hauling it, etc. The rate of pay of the largest number, 86, for all occupations was from $1.50 to $1.74 per day. Those receiving the highest daily rate of pay were engineers, machinists, etc.

Supplies, materials, and miscellaneous expenses.—The amount, $58,073, reported as paid for supplies and materials, is the largest expenditure for any one item excepting wages. Of the amount, $24,893, reported for miscellaneous expenses, $13,326, or 53.5 per cent, was expended for royalties and rent, and $11,567, or 46.5 per cent, for rent of offices, taxes, insurance, interest, and other sundries.

Mechanical power.—Of the 35 operators from whom reports were received, 21 reported the use of power, the total being 1,840 horsepower. Of this, 1,200 horsepower, or 65.2 per cent, was steam; 550, or 29.9 per cent, water wheels; 50, or 2.7 per cent, hydraulic pump; and 40, or 2.2 per cent, gas or gasoline. Of the steam, 545 horsepower, or 45.4 per cent of the total, was used in Pennsylvania; 185, or 15.4 per cent, in Georgia; and the remainder, 470, or 39.2 per cent, in Maryland, New York, and "all other states." Of the water wheels, 500 horsepower was employed in Pennsylvania and 50 in New York. "All other states" had all the gas or gasoline horsepower, and Georgia the hydraulic pump.

Production.—The United States Geological Survey has published annual statistics concerning the quantity and value of mineral paints, beginning with 1894, and of some of the subclassifications from various dates, but these statistics are not comparable with those of the census, for the reason that they include the manufacture of the ore into paints and are not limited to the value of the crude ore at the mines. The Census statistics for 1902 include only that part of the manufacture which is done at the mines and which it is impossible to segregate, the mining and manufacture being in such cases accomplished with the same capital and under the same management. From the reports received for 1902, the various ores and clays from which mineral paints were made ranged in value from $1 (for red rock pigment) to $80 (for zinc white) per ton. The average value per ton was $10.17. Allowance must be made for the great variation in the average value due to the comparatively wide range in quantities and materials. The classification of crude mineral pigments includes yellow, gray, and brown ocher, umber, sienna, zinc white, white mineral (gypsum), slate (sold for pigment), carbonate of iron and of zinc, oxide of iron, and other pigments. With ocher some of the previous censuses have included a little of umber and sienna. Ochers are known as those clays to which the natural mixing of iron peroxide and water has imparted a bright red or reddish-yellow color, while the iron pigments are those from which the darker red or brown paints are made. In the statistics of production given at the census of 1902, there are by-products of 390 tons of soapstone used for pigment, valued at $2,340, and 18 tons of slate, valued at $525. The capital, wages, and other expenses attending the production are given under "Talc and soapstone" and "Slate."

A detailed summary showing the statistics for crude mineral pigments during 1902 is given in Table 3.

DESCRIPTIVE.

Pigments are substances, both natural and artificial, which are usually insoluble in water, oils, and other neutral solvents, and are used to impart color to a body either by surface adhesion or by direct admixture with its substance. Generally there is no chemical combination between the pigment and the body it covers. When mixed with a drying oil, or with water containing oil or size, the pigments form the basis of paint which is used for decorative or protective purposes.

The natural pigments, the only ones with which this report is concerned, are among the most important but are fewer in number than those prepared artificially by chemical precipitation or other processes. According to Thorp[1] the chief pigments are classified as follows: *Whites:* White lead, lead sulphate, lead oxychloride, zinc white, zinc sulphide, barytes, gypsum, and whiting. *Blues:* Ultramarine, Prussian blues, smalt, cobalt blues, copper blues, and indigo. *Violet:* Ultramarine. *Greens:* Ultramarine, Brunswick green, chrome green, Guignet's green, copper greens, and copper and arsenic greens. *Yellows:* Chrome yellow, yellow ocher, cadmium yellow, orpiment, litharge, gamboge, and Indian yellow. *Orange:* Orange mineral, chrome orange, and antimony orange. *Reds:* Red lead, chrome red, red ocher, Venetian red, vermilion, realgar, antimony red, and carmine. *Browns:* Umbers, Vandyke brown, and sepia. *Blacks:* Lampblack, ivory black, boneblack, and graphite.

Iron oxide pigments.—The iron oxide pigments are used to make dark red or brown paints, being known in the trade as "natural reds." They are classed as natural and artificial, the former (metallic paints and mortar color) being chiefly made from brown iron ore and ferruginous shales, and the latter (Venetian red, Tuscan red, and Indian red) from calcining copperas or copperas residues in a furnace yielding ferric oxide (Fe_2O_3) in a state of very fine division.

Although the occurrence of iron ores in the United States is widespread, and enormous deposits exist at many places, there are very few localities in which the material is of suitable physical and chemical composition for manufacture into metallic paint.

The ores reported for use in the manufacture of metallic paint and mineral paint were mined in Anne Arundel and Baltimore counties, Md.; Carbon county, Pa.; James county, Tenn.; Rutland county, Vt.; Bedford county, Va.; and Dodge county, Wis. The mortar colors were all reported from Northampton county, Pa. Other iron pigments reported were mined in Cattaraugus county, N. Y., and Carbon and Wyoming counties, Pa. The Venetian red reported was all mined in Anne Arundel county, Maryland.

The iron oxide paints are highly esteemed for some purposes on account of their freedom from poisonous ingredients which are found in some mineral paints, and because they resist to a marked degree the effects of light, heat, and moisture, a quality which renders them of great value for outside or exposed work. Ochers in addition resist the destructive action of salt air, and are therefore of special value in localities at or near the seacoast.

A certain proportion of metallic paint is used as a coloring matter in mortar making, and appears in some classifications under the title "mortar colors."

The mining and preparation of the crude ore for the market are very simple processes. The ore, generally obtained by open-cut or quarrying methods, is disintegrated by exposure to the atmosphere, carried to a mill, roughly crushed, dried, pulverized, and passed over a screen of bolting cloth or through some type of pneumatic separator, from which the final product is classified and packed for shipment. At times the ground ore is

[1] Outlines of Industrial Chemistry, by F. H. Thorp. New York Macmillan & Co., 1898.

levigated and the settled products dried and packed for shipment.

Ochers.—The name ocher is applied to clays and other earthy bases containing in their natural state sufficient ferrous or ferric oxide or hydroxides to impart to the mass a bright red or yellowish-red tint. The color varies from a golden yellow to a dark red, occasionally possessing various tints of blue and green.

The ochers reported were mined in Clay county, Ark.; Calaveras and Stanislaus counties, Cal.; Bartow and Richmond counties, Ga.; Berks, Lehigh, Luzerne, and Northampton counties, Pa.; Rutland county, Vt.; and Page county, Va. The sienna reported was mined in Washington county, N. Y., and the umber in Lawrence county, Pennsylvania.

The ochers have been used as paints from a very early date, the oldest applications positively recognized having been made in Italy, though it is believed that some varieties were in use still earlier by the Egyptians and Greeks. In modern times the ochers were first mined and prepared in Italy, and the siennas and umbers derive their names from the Italian towns in which they were manufactured into pigments.

Ochers are classified in many ways, according to the locality of occurrence, the composition, and the special shade of color. Practically they may be grouped into yellow, red, and brown. Yellow ocher is that which is colored by a ferric hydroxide. Red ocher owes its tint to ferric oxide, and it is therefore evident that red ocher may be prepared artificially by expelling the water from yellow ocher by calcining in a furnace or kiln. Brown ocher is red ocher modified by the presence of black manganese dioxide, which in various proportions yields a large range of brown colors, notably sienna brown, umber, Vandyke brown, and manganese brown.

The variation of ocher in shade and in quality depends chiefly, but not entirely, upon the proportion of iron oxide present as well as the quantity of water combined with the iron oxide. A red ocher, improperly called iron minium, very rich in iron oxide, is made by calcining and pulverizing limonite that is free from clay.

There are few pigments more free from adulteration than the ochers, for the reason that any filler that can be used advantageously is more costly than the ocher itself. Sometimes a little chrome yellow is added in order to improve the tone of a poor colored ocher, but the presence of this adulterant is very easily detected. Oxford ochers are the brightest and best of the mineral pigments of this class. They are obtained from Oxford, England. The German pigments are often called ochers, although improperly so, for the reason that they are ligneous earths and not ferruginous clays. The manufactured product varies greatly in quality and value, and some of the grades pass insensibly into umber or sienna.

Umber and sienna in reality are varieties of ocher which have been isolated on account of the brown color which is imparted to the natural clay material by the addition of iron and manganese oxides; raw umber is of a brown color, while burnt umber is of a somewhat richer and redder hue. Raw sienna is of a brownish yellow shade which affords a rich russet brown when burned. Intermediate shades of color are obtained by mixing natural products with various properties of iron and manganese oxides, and sometimes by mixing both raw and calcined materials together.

The mining and preparation of ochers, umbers, and siennas are similar to the practice described under iron oxide pigments, with the exception that at times the ground product, in part or wholly, is first heated in a furnace until the desired color has been obtained. In place of levigating and settling the ground material, it is sometimes passed through a pneumatic separator which yields an impalpably fine and uniform product.

Slate, shale, and soapstone.—A few tons each of slate, shale, and soapstone (the last-named being a variety of the mineral talc) are annually ground in the United States to produce a gray-colored pigment used chiefly as a filler for mineral paints, especially those of the variety called fire-retarding.

Gypsum.—Known also as terra alba and mineral white, is a natural hydrated calcium sulphate ($CaSO_4$, $2H_2O$). It is used to a minor extent as a pigment for printing wall paper. The method of making this pigment consists in grinding the mineral and treating it with acid in order to remove any tint or color resulting from the presence of iron oxide. The gypsum, or white mineral reported in 1902 was mined in Cape Girardeau county, Missouri.

Artificial pigments.—In addition to the natural iron oxide pigments, made by a simple washing and grinding of pure crude ores, there are two very important artificial iron oxide pigments made by roasting the residuum obtained from making copperas, or green vitriol ($FeSO_4$,$7H_2O$). One is Venetian red, composed almost wholly of artificial iron sesquioxide, and the other Indian red, which is comprised of about 40 per cent of iron sesquioxide, the balance being mainly calcium sulphate, made by adding a certain proportion of lime during or before the roasting.

There are two methods of manufacturing these artificial reds, the "dry" and the "wet." In the former method, which is the cheaper for the low grades of oxides, the impure copperas is roasted in a furnace with lime or similar material, in order to neutralize the acid in the sulphate until the desired strength and color of the product are obtained. Occasionally copperas alone is roasted until the acid constituent has been completely expelled, leaving the residuum in the form of pure iron sesquioxide; a filler (whiting or gypsum) is then added in proportions to yield the desired grade of Venetian red, some containing as little as 10 per cent of iron oxide or coloring power.

The wet method is cheaper for the manufacture of the general grades of Venetian red, but yields a less uniform product than the dry method. In principle, the waste liquor from the cleansing or pickling process in preparing iron wire or plates for galvanizing by immersion in weak sulphuric acid is treated direct by the addition of milk of lime, sodium carbonate, or similar reagents, which precipitates the iron as a hydrate or carbonate to the bottom of the tank. This precipitate is subsequently separated from the liquor by filtration through a press, the dried cakes remaining therein being subsequently roasted in furnaces, cooled, and packed for the market without grinding. The product made in this manner is not uniform in quality, and has but a limited use.

Hematite ore is sometimes ground and sold as Venetian red. The natural products, however, are inferior to the artificial and do not command as high a price.

Formerly the iron oxide pigments made in the United States did not contain more than 50 per cent of iron oxide, the higher grades being imported. Recently, however, the use of a crucible furnace of special design, which gives good control of the heat and of the oxidation, has raised the grade of the product to practically 100 per cent of iron oxide.

Improvements have also been made in the wet process, chiefly in the substitution of mechanical appliances for hand labor, which has lessened the cost of production and given a more uniform product.

Other mineral pigments.—Among other minerals used in part in the manufacture of paints are barytes, asbestos, graphite, and asphaltum.

The mineral is generally prepared as follows: The crude ore is hand sorted and the limestone rock and other foreign materials removed; the selected ore is then crushed and boiled in dilute sulphuric acid in order to remove any remaining impurities, chiefly iron oxide, which may impart a tint or color to the product. The material is then thoroughly washed after boiling to free it from acid or soluble salts and is finely ground and put on the market in four varieties: No. 1, No. 2, No. 3, and "floated" or water sorted.

Barium sulphate, known as "blanc fixe," which has been precipitated artificially as a by-product in some chemical industries, is used to a considerable extent as a filler and pigment. It has more body and greater capacity and covering power than the native mineral barite, for the reason that it is amorphous while barite is crystalline.

The chief use of barite is as a pigment which is usually mixed with white lead. In the United States it is regarded as an adulterant which depreciates the value of the paint, but in Europe it is considered a valuable addition, and in many cases a pigment composed of a mixture of barite and white lead is considered more serviceable than white lead alone, for the reason that, owing to the insolubility of barite in acids, it imparts elasticity to the mixture, gives a greater body to the paint, and resists the influence of the weather better than white lead alone.

A considerable quantity of barite is used in the form of lithophone, which is an artificial compound of barium sulphate, zinc oxide, and zinc sulphide, obtained by precipitating zinc sulphide and barium sulphate by a mixture of solutions of zinc sulphate and barium sulphide, the precipitate being washed, dried, and calcined. A type composition is given as: Barium sulphate, 68 per cent; zinc oxide, 7.2 per cent; and zinc sulphide, 24.8 per cent. The composition, however, varies with the different makes.

Asbestos can hardly be classed as a pigment, although when used as a filler its white color lightens the color of the material to which it is added. The chief use of asbestos in paint manufacture is to yield a so-called noninflammable or fireproof paint. The fibrous varieties of talc are also used for this purpose. Only a small proportion of the total production of asbestos in the United States is utilized in paint manufacture.

Both the natural mineral and the artificial product made in the electric furnace are used as a black pigment and in pencils, crayons, and in stove polish. The color of the pigment is a dull black and permanent, and on account of its resistance to the action of the atmosphere, as well as that of ordinary chemicals, it is of great value as the basis of a protective paint for coating oxidizable metals, chiefly iron and steel.

The purer grades of asphaltum are largely used as a basis for the manufacture of a black varnish, and as a protective paint for the interior of chlorine stills, bleaching powder chambers, acid tanks, and like apparatus. Asphaltum is not acted upon by ordinary chemicals, and for this reason it is invaluable for protecting structures of iron, steel, and even wood, which would be rapidly destroyed by acid fumes unless coated with some inert material.

Whiting, or Paris white, is composed of calcium carbonate ($CaCO_3$). Calcium carbonate occurs quite extensively in nature, either in the crystalline form, as the well-known mineral calcite, or calc-spar, or in the compact form, such as marble and limestone, or as the soft compact variety known as chalk. It is produced artificially as a by-product of many chemical operations. The whiting used in commerce is generally prepared by grinding and levigating pure chalk, large deposits of which occur, notably in England and France. The chief use of whiting as a pigment is to modify the shade of other pigments. It is also largely used as a basis for whitewash, and when mixed with from 15 to 18 per cent of linseed oil it forms putty.

TABLE 3.—DETAILED SUMMARY: 1902.

	United States.	Georgia.	Maryland.	New York.	Pennsylvania.	All other states.[1]
Number of mines or quarries	35	4	4	5	12	10
Number of operators	35	4	4	5	12	10
Character of ownership:						
Individual	8		2	2	1	3
Firm	5		2	1	1	1
Incorporated company	22	4		2	10	6
Salaried officials, clerks, etc.:						
Total number	63	8			40	15
Total salaries	$53,593	$5,134			$41,002	$7,457
General officers—						
Number	17	3			8	6
Salaries	$26,000	$1,200			$20,300	$4,500
Superintendents, managers, foremen, surveyors, etc.—						
Number	31	4			20	7
Salaries	$19,635	$3,646			$14,032	$1,957
Foremen, below ground—						
Number	3				3	
Salaries	$2,250				$2,250	
Clerks—						
Number	12	1			9	2
Salaries	$5,708	$288			$4,420	$1,000
Wage-earners:						
Aggregate average number	256	65	4	4	148	35
Aggregate wages	$106,087	$19,471	$1,716	$2,257	$67,006	$15,637
Above ground—						
Total average number	204	54	4	4	107	35
Total wages	$84,856	$15,693	$1,716	$2,257	$49,553	$15,637
Engineers, firemen, and other mechanics—						
Average number	33	7	1		18	7
Wages	$19,019	$2,986	$300		$12,219	$3,514
Miners or quarrymen—						
Average number	66	21	2	3	29	11
Wages	$24,590	$5,398	$816	$1,789	$12,035	$4,552
All other wage-earners—						
Average number	105	26	1	1	60	17
Wages	$41,247	$7,309	$600	$468	$25,299	$7,571
Below ground—						
Total average number	52	11			41	
Total wages	$21,231	$3,778			$17,453	
Miners—						
Average number	24	6			18	
Wages	$9,904	$2,254			$7,650	
Miners' helpers—						
Average number	19	3			16	
Wages	$7,728	$900			$6,828	
All other wage-earners—						
Average number	9	2			7	
Wages	$3,599	$624			$2,975	
Average number of wage-earners at specified daily rates of pay:						
Engineers—						
$1.00 to $1.24	3	2			1	
$1.25 to $1.49	1				1	
$1.50 to $1.74	6				3	3
$1.75 to $1.99	1					1
$2.00 to $2.24	4	1	1		2	
$2.50 to $2.74	1					1
$3.00 to $3.24	1					1
Firemen—						
$1.00 to $1.24	1	1				
$1.25 to $1.49	1					1
$1.50 to $1.74	1				1	
$2.00 to $2.24	1	1				
Machinists, blacksmiths, carpenters, and other mechanics—						
$1.00 to $1.24	1	1				
$1.50 to $1.74	1				1	
$2.00 to $2.24	1	1				
$2.50 to $2.74	3				3	
$3.00 to $3.24	6				6	
Miners or quarrymen—						
$0.75 to $0.99	21	21				
$1.00 to $1.24	14	6			8	
$1.25 to $1.49	23		2		17	4
$1.50 to $1.74	24			1	17	6
$1.75 to $1.99	3				2	1
$2.00 to $2.24	4			1	3	
$2.50 to $2.74	1			1		
Miners' helpers—						
$1.00 to $1.24	3	3				
$1.50 to $1.74	11				11	
$1.75 to $1.99	5				5	
Timbermen and track layers—						
$1.50 to $1.74	12				12	
All other wage-earners—						
$0.75 to $0.99	16	15				1
$1.00 to $1.24	32	13			19	
$1.25 to $1.49	13				10	3
$1.50 to $1.74	31			1	20	10
$1.75 to $1.99	6				5	1
$2.00 to $2.24	3		1			2
$2.50 to $2.74	1				1	
Average number of wage-earners employed during each month:						
Men 16 years and over—						
January	239	57	6	1	139	36
February	236	57	6	1	136	36
March	232	57	6	1	132	36
April	237	54	2	4	139	38
May	254	60	2	8	143	41
June	263	70	2	8	139	44
July	268	73	6	8	145	36
August	264	71	6	7	144	36
September	288	68	6	6	172	36
October	280	75	2	4	168	31
November	259	74	2		158	25
December	252	64	2		161	25

[1] Includes operators distributed as follows: Arkansas, 1; California, 2; Missouri, 2; Tennessee, 1; Vermont, 1; Virginia, 2; Wisconsin, 1.

TABLE 3.—DETAILED SUMMARY: 1902—Continued.

	United States.	Georgia.	Maryland.	New York.	Pennsylvania.	All other states.
Miscellaneous expenses:						
Total	$24,893	$1,713	$640	$90	$21,259	$1,191
Royalties and rent of mine and mining plant	$13,326	.....	$600	$25	$12,651	$50
Rent of offices, taxes, insurance, interest and other sundries	$11,567	$1,713	$40	$65	$8,608	$1,141
Cost of supplies and materials	$58,073	$13,146	$1,250	$735	$22,816	$20,126
Product:						
Quantity, short tons	35,479	5,688	2,520	1,261	20,807	5,203
Value	$360,885	$48,423	$10,950	$4,251	$246,346	$50,915
Power owned:						
Total horsepower	1,840	235	50	75	1,045	435
Engines—						
Steam—						
Number	27	6	1	1	13	6
Horsepower	1,200	185	50	25	545	395
Gas or gasoline—						
Number	2	.....	.....	.....	.....	2
Horsepower	40	.....	.....	.....	.....	40
Water wheels—						
Number	9	.....	.....	3	6	.....
Horsepower	550	.....	.....	50	500	.....
Other power—						
Number	1	1	.....	.....	.....	.....
Horsepower	50	50	.....	.....	.....	.....