STONE.

By William C. Day.

ACKNOWLEDGMENTS.

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VALUE OF STONE PRODUCED IN 1895 AND 1896.

The following table shows the value of the different kinds of stone produced in the United States during the years 1895 and 1896:

Value of different kinds of stone produced in the United States during the years 1895 and 1896.

Kind.	1895.	1896.
Granite	$8,894,328	$7,944,994
Marble	2,825,719	2,859,136
Slate	2,698,700	2,746,205
Sandstone	4,211,314	4,023,199
Limestone	15,308,755	13,022,637
Bluestone	a 750,000	a 750,000
Total	34,688,816	31,346,171

a Estimated.

This table shows that marble and slate are the only kinds of stone which advanced in value of amount produced. The values for the other kinds, except bluestone, which is believed to have held its own, have declined. The continuation of the financial depression is believed to be alone accountable for this condition. As is shown in the reports on slate and marble, these two varieties have advanced for special reasons, namely, on the part of slate a marked increase in export trade, and on the part of marble a much greater tendency toward its use for outside building.

VALUE OF STONE PRODUCT IN 1896, BY STATES.

The following table shows the value of the various kinds of stone produced in 1896, by States:

Value of the various kinds of stone produced in 1896, by States.

State.	Granite.	Sandstone.	Slate.	Marble.	Limestone.	Total.
Alabama		$48,000			$180,921	$228,921
Arizona		10,000			18,470	28,470
Arkansas		1,400			30,708	32,108
California	$215,883	7,267		$4,000	143,865	371,015
Colorado	36,517	58,989			65,063	160,569
Connecticut	794,325	426,029			138,945	1,359,299
Delaware	67,775					67,775
Florida					16,982	16,982
Georgia	274,734	1,250	$20,388	617,380	29,081	942,833
Idaho	3,037	16,060		5,500	5,662	30,259
Illinois		15,061			1,261,359	1,276,420
Indiana		32,847			1,658,499	1,691,346
Iowa		12,351		39,740	410,037	462,128
Kansas		18,804			158,112	176,916
Kentucky					135,967	135,967
Maine	1,195,491		124,086		608,077	1,927,654
Maryland	251,108	10,713	72,142	110,000	261,278	708,241
Massachusetts	1,656,973	304,361	1,200	83,904	118,622	2,165,060
Michigan		111,321			109,427	220,748
Minnesota	155,297	202,900			228,992	587,189
Missouri	107,710	51,144			802,968	961,822
Montana		3,250			83,927	87,177
Nebraska					10,655	10,655
Nevada	1,250					1,250
New Hampshire	497,966					497,966
New Jersey	204,323	126,534	700		134,213	465,770
New York	161,167	223,175	82,492	484,160	1,591,966	2,542,960
North Carolina	40,017	13,250				53,267

Value of the various kinds of stone produced in 1896, by States—Continued.

State.	Granite.	Sandstone.	Slate.	Marble.	Limestone.	Total.
Ohio		$1,679,265			$1,399,412	$3,078,677
Oregon	$2,449				1,600	4,049
Pennsylvania	159,317	$446,926	$1,726,318	$31,522	2,104,774	4,468,857
Rhode Island	746,277				11,589	757,866
South Carolina	55,320				26,000	81,320
South Dakota	199,977	37,077			3,126	240,180
Tennessee		4,100	1,420	381,373	157,176	544,069
Texas		36,000			77,252	113,252
Utah	886	7,860			9,358	18,104
Vermont	895,516		609,596	1,101,557	147,138	2,753,807
Virginia	95,040		107,863		182,640	385,543
Washington		11,090			83,742	94,832
West Virginia		24,693			59,113	83,806
Wisconsin	126,639	65,017			552,921	744,577
Wyoming		16,465				16,465
Totals	7,944,994	4,023,199	2,746,205	2,859,136	13,022,637	30,596,171

GRANITE.

The following table shows the value of the granite output in 1896, by States:

Value of granite product in 1896, by States.

State.	Value.	State.	Value.
California	$215,883	New York	$161,167
Colorado	36,517	North Carolina	40,017
Connecticut	794,325	Oregon	2,449
Delaware	67,775	Pennsylvania	159,317
Georgia	274,734	Rhode Island	746,277
Idaho	3,037	South Carolina	55,320
Maine	1,195,491	South Dakota	199,977
Maryland	251,108	Utah	886
Massachusetts	1,656,973	Vermont	895,516
Minnesota	155,297	Virginia	95,040
Missouri	107,710	Wisconsin	126,639
Nevada	1,250	Total	7,944,994
New Hampshire	497,966		
New Jersey	204,323		

Value of granite paving blocks made in 1895 and 1896, by States.

State.	1895.	1896.
California	$34, 079	$73, 390
Connecticut	46, 830	32, 592
Delaware	16, 556	17, 074
Georgia	232, 041	94, 390
Maine	636, 063	344, 101
Maryland	2, 633	33, 933
Massachusetts	496, 544	324, 784
Minnesota	4, 800	....
Missouri	22, 014	27, 911
New Hampshire	16, 823	26, 353
New Jersey	39, 389	14, 847
New York	16, 443	24, 389
North Carolina	1, 320	1, 554
Oregon	....	210
Pennsylvania	69, 503	65, 580
Rhode Island	49, 255	50, 851
South Carolina	12, 505	4, 644
South Dakota	20, 800	28, 326
Vermont	30, 702	30, 990
Virginia	8, 028	10, 129
Wisconsin	17, 000	25, 688
Total	1, 773, 328	1, 231, 736

The value of the total granite output in the United States in 1896 falls below that of 1895 by $949,334. This is not so great a difference as that between the figures of 1895 and 1894, but it is nevertheless a serious falling off, due, as heretofore, only to the general depression. It would be a very serious mistake to ascribe the decline in granite output to anything else than hard times, for never before was it put to a larger number of uses than at present, and its popularity for monumental and cemetery work is steadily increasing. It is being used more and more in the form of polished pillars and slabs in our public buildings, while even houses built in blocks for renting in some of our large cities, notably Philadelphia, are to be seen with polished granite pillars supporting the roof covering front porticos. The enduring qualities of granite are sure to appeal to good judgment in building, and where expense is not too serious a consideration granite will have preference over a number of other kinds of building and ornamental stone. The expense attached to the use of granite is largely a consequence of the difficulties in cutting, polishing, and ornamenting it. The price of crude granite for monumental use runs from 70 cents to $1.50 per cubic foot, while the price of crude marble for the same kind of use runs from $2.25 to $12 per foot.

While marble costs more to quarry, since it has to be cut out by channeling machines and drills, it is more easily cut, polished, and ornamented, owing to its greater softness, and hence such work costs less than the same applied to the comparatively very hard granite.

Improvements in machinery for handling granite and also for cutting, polishing, and ornamenting tend to reduce the cost of manufacture to some extent, although prices for finished granite monumental stock are quite firmly maintained in spite of reduced cost of working it.

The table on the next page shows the condition of the granite industry in the various producing States for all years since 1889.

VALUE OF THE GRANITE PRODUCT, BY STATES, FROM 1890 TO 1896.

The following table gives the value of the granite output, by States, for the years 1890 to 1896:

State.	1890.	1891.	1892.	1893.	1894.	1895.	1896.
Arkansas	(a)	$65,000	$40,000	....	$28,100	....	....
California	$1,329,018	1,300,000	1,000,000	$531,322	307,000	$348,806	$215,883
Colorado	314,673	300,000	100,000	77,182	49,302	35,000	36,517
Connecticut	1,061,202	1,167,000	700,000	652,459	504,390	779,361	794,325
Delaware	211,194	210,000	250,000	215,964	173,805	73,138	67,775
Georgia	752,481	790,000	700,000	476,387	511,804	508,481	274,734
Idaho	....	....	....	....	....	14,560	3,037
Maine	2,225,839	2,200,000	2,300,000	1,274,954	1,551,036	1,400,000	1,195,491
Maryland	447,489	450,000	450,000	260,855	308,966	276,020	251,108
Massachusetts	2,503,503	2,600,000	2,200,000	1,631,204	1,994,830	1,918,894	1,656,973
Minnesota	356,782	....	360,000	270,296	153,936	148,596	155,297
Missouri	500,642	400,000	325,000	388,803	98,757	128,987	107,710
Montana	(a)	51,000	36,000	1,000	5,800	....	....
Nevada	(a)	....	....	3,000	1,600	3,200	1,250
New Hampshire	727,531	750,000	725,000	442,424	724,762	480,000	497,966
New Jersey	425,673	400,000	400,000	373,147	310,965	151,343	204,323
New York	222,773	225,000	200,000	181,449	140,618	68,474	161,167
North Carolina	146,627	....	150,000	122,707	108,993	75,000	40,017
Oregon	44,150	3,000	6,000	11,255	4,993	1,728	2,449
Pennsylvania	623,252	575,000	550,000	206,493	600,000	300,000	159,317
Rhode Island	931,216	750,000	600,000	509,799	1,211,439	968,473	746,277
South Carolina	47,614	50,000	60,000	95,443	45,899	22,083	55,320
South Dakota	304,673	100,000	50,000	27,828	8,806	33,270	199,977
Texas	22,550	75,000	50,000	38,991	....	....	....
Utah	8,700	....	15,000	590	....	....	886
Vermont	581,870	700,000	675,000	778,459	893,956	1,007,718	895,516
Virginia	332,548	300,000	300,000	103,703	123,361	70,426	95,040
Washington	(a)	....	....	....	....	....	....
Wisconsin	266,095	406,000	400,000	133,220	166,098	80,761	126,639
Total	14,464,095	13,867,000	12,642,000	8,808,934	10,029,156	8,894,328	7,944,994

a Granite valued at $76,000 was produced in Arkansas, Montana, Nevada, and Washington together, and this amount is included in the total.

The table on the next page shows the purposes for which the granite was sold by the quarrymen. The column headed "Sold in rough state" shows how much stone was sold in rough condition without any special squaring up or dressing. The purposes which such stone ultimately served is a matter of question, as it was disposed of by the quarrymen to builders, monument and tombstone cutters, and to others for uses which could not be ascertained from the quarrymen. In spite of the difficulty thus indicated, however, the table will probably be found of interest in showing, for example, just how far the quarrymen go in preparing their product for immediate consumption without the intervention of others.

Granite production in the United States in 1896, by States and uses.

State.	Sold in rough state.	Building purposes.	Monumental and cemetery purposes.	Paving blocks.	Macadamizing purposes.	Other.	Total.
California	$27,200	$79,225	$16,003	$73,390	$9,814	$10,251	$215,883
Colorado	3,743	30,802	1,972				36,517
Connecticut	512,352	120,080	91,121	32,592	35,580	2,600	794,325
Delaware	38,190	10,461	500	17,074		1,550	67,775
Georgia	29,127	64,093	11,900	94,390	11,634	*a* 63,590	274,734
Idaho	3,037						3,037
Maine	187,855	470,838	80,564	344,101	7,300	*b* 104,833	1,195,491
Maryland	68,671	129,927	5,073	33,933		*c* 13,504	251,108
Massachusetts	538,907	569,829	185,987	324,784		*d* 37,466	1,656,973
Minnesota	10,431	113,113	29,153			*a* 2,600	155,297
Missouri	7,120	32,190	12,928	27,911	25,356	*a* 2,205	107,710
Nevada		500	750				1,250
New Hampshire	151,975	194,926	119,460	26,355		*e* 5,250	497,966
New Jersey	11,016	27,255		14,847	151,205		204,323
New York	20,539	71,672	14,613	24,389	28,298	*a* 1,656	161,167
North Carolina	2,583	6,281	72	1,554		*a* 29,527	40,017
Oregon	78		51	210	1,876	234	2,449
Pennsylvania	66,427	12,683	565	65,580	12,487	*a* 1,575	159,317
Rhode Island	90,219	199,487	366,840	50,851	30,000	*a* 8,880	746,277
South Carolina	692		12,375	4,644		*f* 37,609	55,320
South Dakota	4,951	9,000	7,700	28,326	150,000		199,977
Utah	516	296	74				886
Vermont	431,928	28,200	404,398	30,990			895,516
Virginia	15,706	46,686	17,887	10,120		*a* 4,641	95,040
Wisconsin	9,419	14,533	57,079	25,688	13,500	*a* 6,420	126,639
Total	2,232,682	2,232,077	1,437,065	1,231,729	477,050	334,391	7,944,994

a All curbing; *b* $70,433 for curbing, $34,400 for bridge work; *c* $3,680 for bridge work, $3,924 for curbing, $5,000 for riprap; *d* $23,745 for curbing, $9,000 for building; *e* $4,700 for curbing, *f* $37,500 for ballast.

ELECTRICITY IN STONE QUARRIES AND YARDS.

The following is an abstract of an article in Stone for July, 1896:

The transmission of power through the agency of electricity has been tried at a number of European stone quarries, and notably by the Hainaut quarries, at Soignies, Belgium. By the present process of transmitting power by steam there is much loss by condensation of steam in passing through long pipes, particularly in cold weather. By the use of electricity this is of course avoided, and the number of employees needed is reduced. The quantity of fuel necessary is much smaller, while the ease with which speed is controlled in electrical apparatus does away with objections made to steam apparatus because of its sudden, jerky action, and naturally reduces the expense for repairs. At the plant above-mentioned a single Sulzer compound engine of 300 horsepower moves saws and runs two generators for mixed service, such as lighting, running pumps, capstans, and cranes, etc. Immense blocks of stone are handled by a traveling crane of 60 tons capacity run by an electric motor.

The success which has attended the innovations of the Hainaut company is attested by the fact that in 1894 substantial additions to the original plant were made.

PNEUMATIC TOOLS AND COMPRESSED AIR.

Pneumatic tools,[1] at first crude and complicated, have been so improved that they now deliver 20,000 blows per minute at a pressure of 80 pounds per square inch. The painful recoil has been done away with by the use of an air cushion. A machine is used for surfacing granite, and a larger tool is employed, mounted on a radial arm supported on a post; these are capable of surfacing 60 square feet of granite per day. Compressed air, as a means of transmitting power for other machines, seems to be rapidly replacing steam, which, owing to leakage and loss of heat, is decidedly less economical than compressed air.

THE GRANITE INDUSTRY IN INDIVIDUAL STATES.

California.—Production declined from a valuation of $348,806 in 1895 to $215,883 in 1896. The granite industry in this State is at a low ebb. This is the almost unanimous verdict of the producers, and recuperation is not expected for several years.

Colorado.—Production increased very slightly, but there has been no radical improvement, and quarrymen say they can not see how the industry could be in any worse condition than at present.

Connecticut.—The output of granite in 1896 was valued at $794,325; business showed considerable improvement, and the value of the output increased from $779,361 in 1895 to the figure named above for 1896.

[1] Stone, September, 1896.

The following gives the results of investigation of a trap rock at Meriden. The stone is used chiefly for road making and was quarried by the Byxbee-De Peyster Trap Rock Company, of Meriden. The mechanical test was made with testing machine at Watertown Arsenal, Massachusetts, by Maj. J. W. Reilly.

Crushing test of trap rock from Meriden, Connecticut.

Test number.	Sectional area.	First crack.	Ultimate strength.	Per square inch.
	Sq. in.	*Pounds.*	*Pounds.*	*Pounds.*
8175	9.61	163,000	335,600	34,920

The following analysis was made at the mineralogical laboratory of Yale University, at New Haven, Connecticut, by Mr. J. H. Pratt, chemist.

Analysis of sample of trap rock from Meriden, Connecticut.

	Per cent.
Silica, SiO_2	52.37
Aluminum oxide, Al_2O_3	15.06
Ferric oxide, Fe_2O_3	2.34
Ferrous oxide, FeO	9.82
Titanium oxide, TiO_2	.21
Manganous oxide, MnO	.32
Magnesium oxide, MgO	5.38
Calcium oxide, CaO	7.33
Potassium oxide, K_2O	.92
Sodium oxide, Na_2O	4.04
Water, H_2O	2.24
Total	100.03

Specific gravity = 2.965.

Granite from a quarry at Greenwich showed a crushing strength of 18,330 pounds and 25,030 pounds to the square inch, and a modulus of rupture of 3,645 and 3,757. The latter test was made by placing a slab 18 inches long, 1 inch wide, and 1 inch thick on the two supports 15 inches apart and adding to a load in the middle until the slab yielded. The load applied in one case was 162 pounds, in another 167, thus giving the moduli of rupture mentioned above.

In regard to the granite quarried by the Columbia Granite Company from a quarry recently developed near the narrows of the Connecticut River, 4 miles southeast of Middletown, the following data have been obtained: The granite is of two varieties, about equal in amount. One is a coarse-grained stone of reddish cast from the flesh-colored feldspar; it contains a finely divided black mica in moderate quantity; it takes a good polish. The other is a fine-grained light-gray stone of compact and uniform structure; it takes a good polish and is well-adapted to monumental purposes. Tests were made by Mr. Ira H. Woolson, M. E.

Crushing tests of granite from Middletown, Connecticut; coarse-grained variety.

[Pounds per square inch.]

NINE SAMPLES FROM NORTHWEST END OF LEDGE.

Bed	23,000	Bed	22,525	Bed	23,542
Edge	21,450	Bed	22,475		
Edge	21,019	Bed	23,525	Average	23,029
Edge	24,278	Edge	25,450		

SEVEN SAMPLES FROM MIDDLE OF LEDGE.

Bed	21,460	Bed	21,921	Edge	20,470
Bed	22,058	Edge	22,797		
Bed	24,753	Edge	21,831	Average	22,184

Final average, 22,600 pounds per square inch.

Crushing tests of granite from Middletown, Connecticut; fine-grained gray variety.

[Pounds per square inch.]

Bed	32,525	Bed	32,500	Bed	34,075
Bed	31,019	Bed	32,562	Edge	32,050
Bed	32,700	Bed	30,000	Edge	30,888
Edge	30,050	Bed	29,400	Bed	32,150

The following tabular statement shows the details involved in making the tests. The pieces used were all cubes:

Tests of granite from Middletown, Connecticut.

COARSE-GRAINED GRANITE.

[Mark: "N. W. end of ledge."]

Test number.	How tested.	Length or height.	Diameter or breadth.	Thickness.	Area.	First crack.	Stress in pounds compression; maximum. On specimen.	Per square inch.
		Inches.	*Inches.*	*Inches.*	*Sq. in.*	*Pounds.*	*Pounds.*	*Pounds.*
1045	Bed...	2.004	2.00	2.00	4.00	91,600	92,000	23,000
1046	Edge..	2.002	2.00	2.00	4.00	84,000	85,800	21,450
1047	Edge..	1.994	2.01	2.00	4.02	83,800	84,500	21,019
1048	Edge..	2.005	2.01	2.00	4.02	97,500	97,600	24,278
1049	Bed...	2.002	2.00	2.00	4.00	....	90,100	22,525
1050	Bed...	2.001	2.00	2.00	4.00	....	94,100	23,525
1051	Bed...	2.001	2.00	2.00	4.00	89,000	89,900	22,475
1052	Edge..	2.001	2.00	2.00	4.00	101,000	101,800	25,450
1053	Bed...	2.010	1.99	2.00	3.98	85,000	93,700	23,542

Tests of granite from Middletown, Connecticut—Continued.

FINE-GRAINED GRAY GRANITE.

[Mark: "South end B."]

Test number.	How tested.	Length or height.	Diameter or breadth.	Thickness.	Area.	First crack.	Stress in pounds compression; maximum.	
							On specimen.	Per square inch.
1054	Bed...	2.007	2.00	2.00	4.00	126,500	130,100	32,525
1055	Bed...	2.002	2.00	2.01	4.02	95,500	124,700	31,019
1056	Bed...	2.007	2.00	2.00	4.00	129,000	130,800	32,700
1057	Edge..	2.001	2.00	2.00	4.00	119,000	120,200	30,050
1058	Bed...	2.000	2.00	2.00	4.00	....	130,000	32,500
1059	Bed...	2.002	1.99	2.00	3.98	128,900	129,600	32,562
1060	Bed...	2.007	2.01	2.00	4.02	110,000	120,600	30,000
1061	Bed...	2.001	2.00	2.00	4.00	....	117,600	29,400
1062	Bed...	1.998	2.00	2.00	4.00	135,000	136,300	34,075
1063	Edge..	2.001	2.00	2.00	4.00	127,800	128,200	32,050
1064	Edge..	1.999	1.99	1.99	3.94	....	121,700	30,888
1065	Bed...	2.004	2.00	2.00	4.00	128,000	128,600	32,150

COARSE-GRAINED GRANITE.

[Mark: "Middle ledge B."]

1066	Bed...	2.026	2.01	2.01	4.04	85,000	86,700	21,460
1067	Bed...	2.025	2.02	2.02	4.08	89,000	90,000	22,058
1068	Bed...	2.007	2.01	2.02	4.06	100,000	100,500	24,753
1069	Bed...	2.011	2.01	2.02	4.06	....	89,000	21,921
1070	Edge..	2.013	2.00	2.02	4.04	91,000	92,100	22,797
1071	Edge..	2.027	2.01	2.01	4.04	76,000	88,200	21,831
1072	Edge..	2.016	2.01	2.01	4.04	81,000	82,700	20,470

Delaware.—The industry in this State fell off slightly. Although operations for the entire State are not large, quarrying methods are advanced and well conducted. Improvement in the magnitude of business will follow the advent of the expected prosperity.

Georgia.—Production in 1896 fell off very markedly, namely, from a valuation of $508,481 in 1895 to $274,734 in 1896. No improvement is expected until the general conditions of trade become better. Maj. J. W. Reilly, of the Watertown Arsenal, found for the Stone Mountain granite a crushing strength of 25,630 and 28,130 pounds per square inch, both on bed; for Lithonia stone, 30,320, 28,290, and 28,250, all on bed. Results of another series of tests of Lithonia granite are as follows. Tests made by Mr. John Bradley.

Crushing tests of granite from Lithonia, Georgia.

[Pounds per square inch.]

No.		No.	
1	31,260	5	30,690
2	31,690	6	33,750
3	28,980	Average	31,816
4	34,530		

Maine.—The value of the product in 1895 was $1,400,000; in 1896 the corresponding figure was $1,195,491. The producers have made many complaints of trade depression, but most of them are hopeful of better things in 1897.

The late Prof. J. S. Newberry, of the School of Mines, Columbia College, New York, made the following report concerning granite from Pleasant River, Maine:

Properly speaking the stone is a diorite, being composed of black hornblende and albite or white feldspar as essentials, a small amount of quartz, and the usual accessories. The hornblende, owing to its toughness, gives the stone a superior cleavage, while albite is one of the hardest and most durable of the feldspars. The stone is very strong, homogeneous, and handsome, and is quite unlike any other building or ornamental stone now in use in this country. It will not rust on exposure, and, as hornblende is substituted for mica in its composition, it takes a fine polish, which will be permanent. The hammer-dressed surfaces are light gray, almost white, and the strong contrast between this and the dark color of the polished surfaces is a very desirable feature, as it brings out strongly any ornamental designs or lettering that may be placed upon it. It withstood a pressure of 22,410 pounds to the square inch.

Though the stone somewhat resembles in appearance some varieties of dark serpentine now in use, it has a totally different composition, and will resist exposure to the weather, as the serpentines and verd antiques will not. It is well adapted to building and monumental purposes, and will be prized by architects as affording a new, attractive, and excellent element for combination with contrasting materials for decorative designs.

Tests of granite quarried at North Jay, Franklin County, Maine.

Sectional area	square inch	36.36
Weight	pounds	20½
Tested between flat steel plates.		
Ultimate strength	pounds	459,000
Ultimate strength	pounds per square inch	12,624
Snapping sound heard at	pounds	190,000
No cracks in sight.		
Corner along one edge split off	pounds	260,000
Block suddenly flew into fragments when maximum strain was reached.		
Test at Watertown Arsenal, May 6, 1882.		

The following statements by Mr. F. L. Bartlett, of the Maine State assay office, have been made relative to the granite at Freeport, Cumberland County, quarried by Mr. E. B. Mallet, jr.:

Characteristics of granite from Freeport, Maine.

Specific gravity	2.627
Hardness	Medium
Iron in form of pyrite	None
Iron in form of oxide, in combination	1.872
Percentage insoluble in strong acids (quartz)	95.2
Percentage soluble in dilute acids	None
Absorption in water	None appreciable

The examination of this granite, as shown by the above tests, indicates that it contains an excess of silica, and that it contains no sulphides of iron or lime; that it is compact and insoluble in water; all of which proves that the stone is suitable for monumental purposes, and will stand under either salt or fresh water. Its composition is silica, black mica, and feldspar. The silica predominates; consequently it would be called quartzose granite.

The Chase Granite Company, operating quarries at Blue Hill, Hancock County, submit the following analysis of the granite quarried by them. The analysis was made in May, 1896, by Messrs. Ricketts and Banks, chemists, of New York City:

Analysis of granite from Blue Hill, Maine.

	Per cent.
Silica	73.02
Protoxide of iron	2.59
Alumina	16.22
Protoxide of manganese	Trace.
Lime	.94
Magnesia	Trace.
Potash	3.42
Soda	3.60
Sulphur	None.
Loss and undetermined	.21
Total	100.00

Maryland.—The output of granite in 1895 was valued at $276,020; in 1896 the figure was $251,108. This of course indicates a slight falling off, but not a serious one, and it is entirely due to the continued financial depression. Producers generally anticipate much improvement in the industry as soon as the hard times have passed. The following data relative to the Port Deposit granite are submitted. The analysis was made by Mr. William Bromwell, under the supervision of

Dr. H. N. Morse, professor of analytical chemistry in the Johns Hopkins University. The stone is quarried by Messrs. McClenahan & Bro., of Port Deposit.

Analysis of granite from Port Deposit, Maryland.

	Per cent.
Silica, SiO_2	73.690
Alumina, Al_2O_3	12.891
Ferric iron, Fe_2O_3	1.023
Ferrous oxide, FeO	2.585
Lime, CaO	3.737
Magnesia, MgO	.498
Potash, K_2O	1.481
Soda, Na_2O	2.811
Water, H_2O	1.060
Total	99.776

The rock also contains a small percentage of titanium (TiO_2), which was not accurately determined, but which is probably about 0.50 per cent. There are also traces of cerium, strontium, barium, manganese, lithium, and phosphoric acid.

The following mineralogical description of the Port Deposit granite was prepared by Prof. G. P. Grimsley, of the Johns Hopkins University:

The proportionate mineral composition of this Port Deposit rock was calculated from the chemical analysis made by Mr. William Bromwell. Such a calculation could be only an approximation for two reasons: First, because the exact composition of the individual minerals in the rock is not known; second, because certain of the bases enter into two or more of the silicates. Although a little secondary muscovite occurs in the feldspar, this was ignored, and the proportion of orthoclase was first calculated, it being assumed that all the potash was contained in this mineral. The soda was in like manner referred to the albite molecule in the plagioclase. The magnesia was regarded as being confined entirely to the biotite. A small proportion of the lime (1 per cent) was arbitrarily assumed to represent approximately the epidote, which is small in amount as seen from this section, while the remainder was referred to the anorthite molecule of the feldspar. The residual silica represents the quartz.

For those minerals which have a definite composition, like orthoclase, albite, anorthite, and quartz, the theoretical proportions of the constituents were used as given in E. S. Dana's System of Mineralogy (edition of 1893). From such a calculation, taken in connection with a mechanical separation in a heavy solution and a study of the relative areas occupied by these minerals in the thin sections, the following percentages are thought to fairly represent the rock:

Mineral composition of granite from Port Deposit, Maryland.

		Per cent.		
	Biotite (mica)	9.7		
	Orthoclase (potash-feldspar)	9.0		46.4
Feldspar (oligoclase)	Albite	23.8	37.4	
	Anorthite	13.6		
	Quartz	40.0		
	Epidote	3.9		
	Total	100.0		

This represents an acid soda-granite of true igneous origin which has subsequently been foliated through pressure.

The following physical tests of Port Deposit granite were made by Messrs. Booth, Garrett, and Blair, of Philadelphia, on a 2-inch cube: Crushing strength, 84,730 pounds for 2 inches; equivalent to 21,180 pounds per square inch.

Massachusetts.—The output of 1895 was valued at $1,918,894; in 1896 the corresponding figure was $1,656,973. There has been evidently a decrease in product. Many producers speak in a decidedly discouraged tone, but feel that as the situation can hardly become worse there must soon be a change for the better.

The following data relative to the character of granite in different localities have been obtained:

Granite from near Westford, Middlesex County, quarried by Messrs. H. E. Fletcher & Co., showed a crushing test of 16,091 pounds to the square inch. Size of specimen, 4.10 by 4.04 by 3.97 inches. First crack occurred at 116,000 pounds. Ultimate strength, 258,100 pounds, equal to 16,091 pounds to the square inch. The test was made at the Watertown Arsenal.

The W. N. Flynt Granite Company, of Monson, report the following facts relative to trap rock quarried by them: The Highway Commissioner of Massachusetts determined what is known as the "coefficient of wear" to be 22.13. The following analysis of same is credited to the Watertown Arsenal:

Analysis of granite from Monson, Massachusetts.

	Per cent.
Silica	52.59
Ferric oxide	14.55
Alumina	23.42
Lime	9.05
Magnesia	.28
Manganous oxide	.09
Total	99.98

The following facts as to Chester granite, quarried at Chester, Hampden County, were submitted by the Hudson and Chester Granite Company:

Prof. B. K. Emerson, of Amherst College, makes the following statements relative to this granite: Its color is a clear gray. It is of fine and even grain, and has strength abundantly sufficient for all architectural demands. A microscopical examination detects no constituents which can impair its durability or cause it to tarnish under the influence of the weather. Pyrite is present in minute quantity, but it shows no tendency to rust. The evenness of the color and grain and the absence of all banding and blotching are all that could be desired, and this enables the quarry to furnish a stone which will meet all architectural demands, and will satisfy the more exacting requirements of the higher classes of monumental work.

Prof. J. F. Kemp, of Columbia College, New York, states that the granite has a gray or bluish-gray color of a medium shade and is very pleasing in its appearance. It is very homogeneous and of moderately fine grain, and has a texture well adapted to tool treatment.

The minerals entering into the stone are quartz, orthoclase and plagioclase feldspar, green biotite and colorless muscovite (i. e., dark and light colored mica), a little magnetite, and a few rare accessory minerals. The several sections failed to show pyrite, and although the chemical analysis indicates it in a very small amount, it is quite insignificant, and need not be feared, either as a source of weakness or of stains.

The chemical analysis gave the following results:

Analysis of granite from Chester, Massachusetts.

	Per cent.
Moisture yielded at 110° C	0.08
Further loss on ignition	0.74
Silica (SiO_2)	69.465
Ferric oxide (Fe_2O_3)	2.30
Alumina (Al_2O_3)	17.50
Manganous oxide (MnO)	Trace.
Lime (CaO)	2.57
Magnesia (MgO)	0.305
Potash (K_2O)	4.07
Soda (Na_2O)	3.01
Sulphur (S)	0.04
Total	100.080

This analysis indicates a granite with a medium percentage of silica, and with nothing of unusual or deleterious character in its composition.

The sulphur, which is present as pyrite (the sulphide of iron), is practically insignificant. A few minute specks are the only signs of it to the eye. The amount of iron is quite low.

Minnesota.—Production in 1895 amounted in value to $148,596; in 1896 the corresponding figure was $155,297, showing an increase of nearly $7,000. Under prosperous conditions the granite industry would probably progress regularly. In 1892 the value of the output was $360,000, showing what can be done under flourishing conditions.

Missouri.—Production fell off from a valuation of $128,987 in 1895 to $107,710 in 1896. The following is an abstract of a paper by Prof. Charles R. Keyes, State geologist of Missouri:

The granites are confined to the southeastern part of the State, where they occur in irregular masses and isolated hills extending over an area of 3,000 square miles. Granites and porphyries are the principal types, with several varieties of dark trappean rocks, chiefly diabase, occurring in the form of dikes. They are the most ancient rocks of the State.

The approximate center of the crystalline district is Pilot Knob, Iron County. For a distance of perhaps 12 miles in all directions from this point the massive crystallines form the greater portion of the surface rock, while in an easterly direction they are practically continuous for more than twice as far. To the north the exposures do not reach much beyond Bismarck, St. Francois County. Northeastward they are found in St. Genevieve County, 30 miles from Pilot Knob. On the east, hills of similar rock are abundant as far as Castor Creek, in Madison County. To the south they stretch away in large masses for many miles, with occasional outcrops as far as the boundary line of Butler County. To the northwest they extend into Shannon County, and perhaps even beyond. They stretch out to the west almost unbrokenly to the east fork of Black River, while numerous scattered hills continue even beyond the middle fork of the same stream. Toward the north similar rocks occur at short intervals as far as Little Pilot Knob, in Washington County. The stone has been used in Dallas, Kansas City, Omaha, St. Louis, Des Moines, Minneapolis, New Orleans, Chicago, Indianapolis, Cincinnati, Cleveland, and Baltimore.

It has been demonstrated that apparent lines of sedimentation in this rock are really pseudo-stratification planes, and that they have been developed in a way that is widespread among rocks that have cooled from molten magmas. The continuity of the massive rocks is interrupted by numerous lines. The porphyry appears to be the surface facies of the coarse grained granite, and seems to graduate downward into the latter. The numerous lines of fracture are most of them merely joint planes; many are slight fault lines, while still others have the walls spread apart, the space being filled with basic material which often forms dikes, sometimes of considerable breadth.

Dikes of basic rock occur rather abundantly. They range from a few inches to 50 yards or more in width, and cut the granites and porphyries alike. Nowhere have they been observed to penetrate the overlying sedimentaries. Their number and wide distribution, the great weight and black color of the rock composing them, and their peculiarities in weathering cause them to attract much attention.

There are four principal kinds of rock that are suitable and available for quarry stones. These are:

1. Granite (biotite-granite or granitite).
2. Syenite (granite-syenite).
3. Porphyry (felsite).
4. Black granite (diabase-greenstone).

Typical granite constitutes about one-fifth part of all the crystallines in the district under consideration. In color the stone is a warm red to pink, in places merging into gray. Though usually a coarse-grained rock, fine-grained varieties are of frequent occurrence. The rocks consist almost entirely of a granular aggregate of quartz and feldspar; white mica is entirely absent. The black mica (biotite) present, which is usually one of three essential constituents and a mineral which is the first of the principal components in most granites to break down under meteoric influences, is reduced to minimum, and in many cases it is almost entirely absent. The feldspar is for the most part orthoclase, the most durable of feldspathic minerals. Accessory components liable to decomposition are wanting.

The porphyry is close grained, glassy, of various colors—pink, red, purple, green, brown, and black in many shades. It polishes brilliantly, is hard and rather brittle. It is not suited to dimension work on account of difficulty of working. The groundmass is dense and fine grained, though there are scattered large crystals of quartz and feldspar.

The black granites are greenstones or diabases; they occur in dikes, cutting the granite and porphyry; are heavy, tough, and admit of fine polish; are not desirable for building, but are unsurpassed for paving blocks, decaying fast enough not to become slippery.

The following table shows the results of chemical analyses:

Analyses of granite from the region of Graniteville, Missouri.

Locality.	Loss at 100°C.	Loss on ignition.	SiO_2.	Al_2O_3.	F_2O_3.	FeO.	NiO.	MnO.	CaO.	MgO.	K_2O.	Na_2O.	P_2O_5.	TiO_2.	Totals.	Authority.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	
Graniteville		0.52	77.05	11.77	2.33				2.21		3.88	2.90	0.023		100.68	Melville.
Ironton, 6 miles E	0.14	.85	69.94	15.19	1.88	0.60		0.03	1.15	0.92	4.29	3.95	.13	0.25	99.32	Do.
Silver Mine, 2 miles W			73.98	14.32					1.04		3.32	4.56				St. L. Samp. Works.
Middlebrook, 5 miles E			77.04	12.29												Do.
Hogan, 7 miles E			74.06													Melville.
Do			77.38													Do.
Ironton, 6 miles E	.22	.54	72.35	13.78	1.87	.36	0.20	.06	.87	.42	4.49	4.14	.13	.44	99.87	Do.
Skrainka			69.51													Bradford.

The granite is a mixture of quartz and feldspar, with some biotite as an essential component. Accessory constituents are apatite, zircon, and magnetite. Biotite and hornblende are comparatively rare. Biotite is an important constituent in only a few cases. It is unevenly distributed, so that at some points the rock is quite mottled, though only a short distance away the mica is entirely absent. Hornblende has been observed in a few instances, and then only very sparingly. The feldspars show little indication of decomposition, which is a very favorable point in determining the value of a rock for building purposes.

The rock is jointed in such a way as to make quarrying both easy and economical. The space between the fractures varies at different points. In some cases they are close enough together to permit paving blocks to be taken out with the greatest facility; in other places monoliths of any practical size may be readily obtained perfectly free from seams and defects. Very little stripping is required.

The Syenite Granite Company, of Graniteville, submits the following facts, ascertained by Prof. J. B. Johnson, of the department of civil engineering of Washington University: The two specimens of granite which were sent were ground down on their top and bottom faces to true parallel planes, leaving prisms which were 3.85 square inches and 3.87 square inches in area, respectively. These specimens broke, the former at 93,100 pounds, or 24,200 pounds per square inch, and the latter at 95,700 pounds, or 26,400 pounds per square inch.

Nevada.—Very little granite is produced at present. The following is a statement of the results of analysis of granite produced in Washoe County by Mr. John Barrett. The analysis was made by Prof. J. W. Phillips, chemist:

Analysis of granite from Washoe County, Nevada.

	Per cent.
Silica, SiO_2	58.67
Alumina, Al_2O_3	14.89
Manganese, MnO_2	1.00
Ferric oxide, Fe_2O_3	7.56
Lime, CaO	5.68
Magnesia, MgO	1.79
Soda, Na_2O	7.69
Potash, K_2O	2.69
Loss by ignition	.57
Total	100.54

New Hampshire.—New Hampshire is one of the very few States to show a gain in output during 1896. Production advanced from $480,000 in 1895 to $497,966 in 1896.

New Jersey.—Much of the stone output of New Jersey is trap rock, which has a well-established reputation for use as macadam. Most of it is devoted to this purpose.

The value of the output in 1895 was $151,343; in 1896 the figure was $204,323. Thus, there has been a considerable gain in production in spite of the general depression in trade.

New York.—There was a quite decided gain in the output of granite in New York, as will be seen by consulting the tables of production, but the total is still much below what has been done in former years.

North Carolina.—A falling off in output from a valuation of $75,000 in 1895 to $40,017 in 1896 shows the extent to which depression has gone. Demand has been very light. Expectations for much improvement in 1897 are expressed by some of the quarrymen.

The following facts relative to North Carolina granite have been submitted by the Mount Airy Granite Company. Tests of Mount Airy granite by Messrs. Riehle Bros., of Philadelphia, on cubic-inch samples showed the crushing strength to be about 20,000 pounds to the square inch.

Prof. J. A. Holmes, State geologist of North Carolina, makes the following statements relative to the granite quarried by the Mount Airy Granite Company:

A chemical analysis of a sample of granite from the Mount Airy quarry made in the survey laboratory shows only 0.50 per cent of sulphur and 1.94 per cent of iron. The former probably occurred in the form of small pyrite crystals, and the latter comes in part from this source and in part from the biotite mica. Both occur in such small quantities that they can not prove in any way injurious to the stone, and I have been unable to find any other injurious ingredients. The stone is a medium-grain, light-colored biotite-granite, of marked uniformity in color and texture, and, as shown by actual tests, it stands a crushing strain of 18,000 to 20,000 pounds per square inch. It is an excellent stone for general architectural purposes and for Belgian blocks.

The following analysis of Mount Airy granite quarried at Greensboro was made by Prof. C. M. Cresson, of Philadelphia:

Analysis of Mount Airy granite, North Carolina.

	Per cent.
Silica, SiO_2	71.56
Alumina, Al_2O_3	16.79
Oxide of iron, Fe_2O_3	1.87
Lime, CaO	2.93
Magnesia, MgO	.30
Soda, Na_2O	11.96
Sulphuric acid in combination, SO_3	.33
Total	105.74

This granite is well adapted for buildings, possessing sufficient strength and toughness to carry the loads which are ordinarily required for such purposes. The large masses in which the individual components are aggregated give the stone a peculiar brilliancy of appearance. It is beautifully bright, calculated to make handsome buildings, in strong contrast with the somber cast which usually accompanies granite facings. The absence of the deleterious elements which frequently occur in granite, causing strain and disintegration, adds to the value of this stone.

Oregon.—Very little quarrying has been done in Oregon during the past year. That there is plenty of material of desirable quality, both as to strength and beauty, is well shown by the following account of rocks of economic interest and importance in Oregon, by Mr. J. S. Diller, of the United States Geological Survey:

The rocks of the Coast Range of Oregon are chiefly sandstone, shales, and basalts. Although widely distributed, they are not all of economic importance. The shales are of but little use. The calcareous nodules which they contain, abundantly in some places, have been burned to lime, but the amount is very limited.

The sandstones are quarried in many places for building purposes. Those near the coast are generally soft and used chiefly in the construction of jetties. At Tillamook Bay and Coos Bay they are quarried for this purpose within easy reach of tide water.

The principal sandstone quarry of western Oregon is the one at Pioneer, on the Yaquina River, in Lincoln County. At that place the sandstone occurs in massive beds and affords an excellent building stone. Being soft, it is easily shaped and yet is durable, with a good gray color. The heavy beds allow it to be quarried in large pieces, in some cases 10 feet thick. It is carried by the railroad from the quarry to tide water, then towed on barges down the bay. The rock dips gently and a great mass of it is exposed, so that it will evidently furnish material for some time to come.

About 5 miles south of Forest Grove, in Washington County, at Boose's quarry, a solid dark-gray sandstone is taken for building purposes, and is quite extensively used in the surrounding country. The rock contains numerous Miocene fossils.

At several points a few miles south of Corvallis, and at Monroe, still farther south, in Benton County, considerable sandstone has been quarried, but for local use only.

About 2 miles from Jefferson, Marion County, a sandstone has been quarried and used, by Mr. F. Wood, of Albany, in the construction of monuments. It is a dark-gray sandstone, easily cut, and occasionally shows, upon a fresh fracture, irregular areas of bright reflections from the calcareous cement which holds the sand together. The rock being fine grained receives delicate carvings and was used for the ornamental memorial stone from Oregon in the Washington Monument, at the national capital. Small cubes of this sandstone are said to have been tested and to have shown not only a high crushing strength but to stand fire well. This would be expected from the nature of the sand, which is made up largely of volcanic material. Characteristic fossils occur in this region, as well as near Corvallis and at Monroe, showing that the sandstone belongs to the Eocene formation and may be older than the sandstone at Pioneer and the Coast Range, farther northward.

Sandstones are especially abundant in the Coast Range south of the latitude of Eugene City, and are well exposed along the Umpqua and Coos rivers and the forks of the Coquille. A great bluff of sandstone forms the eastern escarpment of the range from Tyee Mountain and Coles Valley to Camas. The same rock continues farther southward, lapping over the older strata, but in places gets coarser grained, and rising higher in the mountains is less available. Along the coast, however, it is much more easily reached. Near Port Oxford, and perhaps other points south of the district embraced in this reconnoissance, the sandstones have been quarried for the San Francisco market.

It is well known from the publications of Mr. Herbert Lang that limestone, sometimes in the form of marble, occurs in a number of places in the Klamath Mountains of southwestern Oregon, as, for example, near Rocky Point, in Jackson County, and on Williams Creek, in Josephine County. Farther northward, upon the borders of the Willamette Valley, shell limestone is said to occur in Marion and Polk counties.

There is also an interesting occurrence in Douglas County, less than a dozen miles southeast of Roseburg. The narrow belt in which the lenticular masses of limestone crop out here and there crosses the south fork of the Umpqua between Dillard and Ruckles, extending northeast toward Peel, for a distance of at least 20 miles. The outcrops best known are at Cooper's and Flint's, and at the quarry of the Variety Marble Company, of Roseburg. At the first two localities it has been burned for lime. At the last locality a mill was erected to saw the marble into slabs. The mill was not running in the summer of 1895. The marble is one of remarkable beauty, being handsomely variegated with red, yellow, gray, and white. Much of the rock is mottled gray, with a multitude of white veins, while other portions are brecciated with brilliant shades of red and yellow, veined with white and irregular areas of gray. The marble when well polished is one of the most beautiful variegated marbles of this country. It appears, however, that different portions of the mass vary considerably in hardness, and this renders it somewhat difficult to work. Furthermore, the quantity exposed at the quarry is quite limited, although farther southward, in the same belt larger lenticular masses are exposed.

Under the head of basalt are included the modern lavas so extensively used for road metal at many places. At Portland they form a portion of the heights, and occur at many points throughout western Oregon. This rock forms the falls of the Willamette at Oregon City, and many of the hills throughout the Great Valley, whose fertility is largely due to the rich soil which the lavas furnish by alteration and disintegration. It is well known that this rock is among the very best material it is possible to obtain anywhere for road construction. In large cities it is sometimes used in the form of paving blocks, but it is also utilized in the form of fine stones for macadamizing. It is thus employed quite extensively in Portland.

One mile south of Dilley, in Washington County, is the county stone quarry for road metal, in this sort of rock. A crusher is located here and the crushed stone is hauled a long way. The good roads of that region show the wisdom of such a provision.

Basalt is one of the most solid and enduring rocks of Oregon, but its hardness and tenacity render it comparatively difficult to trim. On account of its somber color it is little used for building purposes, excepting for foundations. For this purpose it has a wide application. It frequently possesses a columnar jointing that cuts it up into pieces too small for building purposes. Occasionally the columns are sufficiently regular to be used for fence posts without further trimming. This is especially the case along the Rhine, in Germany.

According to the report[1] concerning the stone industry for 1894, granite is quarried in Jackson and Columbia counties, diabase in Lynn County, basalt in Clackimas and Lynn counties, and andesite in Multnomah County. The value of the granite quarried in Oregon in 1890 was $44,150; in 1891, $3,000; in 1892, $6,000; in 1893, $11,255; in 1894, $4,993. The rocks classed above as granite, diabase, basalt, and andesite are all of igneous origin.

Pennsylvania.—The output in 1896 shows a very decided falling off—i. e., from $300,000 in 1895 to $159,317 in 1896. More than half the product is used for paving blocks, and the substitution of asphalt for paving blocks in Philadelphia has very noticeably affected the paving-block industry in Pennsylvania. The use of paving bricks is also considerable. A number of quarrymen ceased operations entirely for the year. The following is a statement of the results of an analysis of granite from Lackawanna County. The analysis was made by Mr. D. W. Humphrey, chemist, of Scranton.

Analysis of granite from Lackawanna County, Pennsylvania.

	Per cent.
Silica, SiO_2	94.16
Oxide of iron, Fe_2O_3	1.16
Alumina, Al_2O_3	3.60
Magnesia, MgO	....
Lime, CaO	....
Soda and potash	.25
Loss by ignition	.80
Total	99.97

[1] Sixteenth Ann. Rept. U. S. Geol. Survey, Part IV, 1895, pp. 444 and 461.

Rhode Island.—The value of the output in 1896 fell below that of 1895 by $222,196. This State generally stands first in the United States for the annual value of monumental stock turned out, but in 1896 Vermont takes first place in this regard. More than half of the value of the output for 1896 was that of monumental stock.

The granite quarried at Westerly has a high reputation for its adaptability to the finest kind of ornamental work and carving.

South Carolina.—A considerable increase in production characterized the year 1896 in this State, namely, from $22,083 in 1895 to $55,320 in 1896. The need of more capital for the working of some of the quarries is felt by the operators.

South Dakota.—Owing to the increased operations of two firms the output of granite in South Dakota increased from $33,279 in 1895 to $199,977 in 1896. Most of the product was used for macadam, and a considerably smaller amount for paving blocks. The productive quarries are in Minnehaha County.

Vermont.—While the output of granite in Vermont fell off from a valuation of $1,007,718 in 1895 to $895,516 in 1896, still the general tone of encouragement expressed by producers is quite different from that which comes from some other granite-producing sections of the country. Barre particularly shows up very well, and, all things considered, the past year may be called a prosperous one for this important locality.

Virginia.—Production in Virginia increased from $70,426 in 1895 to $95,040 in 1896. There is granite of very fine quality in the vicinity of Richmond, and its popularity is attested by a production which amounted in value to $332,548 in 1890. The recent hard times have, however, caused suspension of operations by a number of important firms; hence the decline in output.

Investigation of granite from Henrico County, quarried by Mr. Peter Copeland, showed, as the result of tests at the Watertown Arsenal, the following results:

Tests of granite from Henrico County, Virginia.

Number of specimen.	Height.	Surface.	First crack.	Ultimate total.	Strength in pounds per square inch.
	Inches.	*Sq. in.*	*Pounds.*		
1	1.90	4.00	93,000	102,080	25,520
2	1.90	4.00	103,000	114,500	28,625

Wisconsin.—A stride forward was made in the granite industry in 1896. Production increased from $80,761 in 1895 to $126,639 in 1896.

The following is a statement of the results of an analysis of the granite quarried in Waushara County by the Milwaukee Monument Company.

Analysis of granite from Waushara County, Wisconsin.

	Per cent.
Silica, SiO_2	76.62
Alumina, Al_2O_3	13.02
Ferric oxide, Fe_2O_3	1.01
Lime, CaO	.51
Magnesia, MgO	.05
Soda, Na_2O	2.24
Potash, K_2O	6.38
Total	99.83

MARBLE.

VALUE OF THE MARBLE PRODUCT, BY STATES.

The following table shows the value of the marble produced in the United States during the year 1896, by States:

Value of the marble product for the year 1896, by States.

State.	Value.	State.	Value.
California	$4,000	New York	$484,160
Georgia	617,380	Pennsylvania	31,522
Idaho	5,500	Tennessee	381,373
Iowa	39,740	Vermont	1,101,557
Maryland	110,000		
Massachusetts	83,904	Total	2,859,136

Comparing the product of 1896 with that of 1895 it appears that there has been a gain of $33,417. This increase is not great, but in view of the financial conditions that have prevailed generally it is somewhat surprising that there should have been any advance whatever. The gain in output in New York State is the most noteworthy and has been such as to more than offset a decrease in several other States.

The following table shows the various uses to which the marble quarried in 1896 was put:

Distribution of output in 1896 among various uses.

	Value.
Sold by producers in rough state	$583,690
Sold for outside building	1,036,163
Ornamental purposes	65,365
Cemetery work (monuments and tombstones)	813,146
Interior decoration in buildings	329,804
Other scattering uses	30,968
Total	2,859,136

Inspection of this table shows that the largest single item is "outside building," to which use $1,036,163 worth of marble was applied, or, in other words, 36.2 per cent of the whole.

The uses to which the stone "sold by producers in rough state" is actually put could not be certainly ascertained. It is bought by builders, stonecutters, and finishing mills. Supposing it to be divided equally between "outside building," "cemetery work," and "interior decoration," this would increase these items by $194,563 in each case, making the amount devoted to outside building, $1,230,726; cemetery work, $1,007,709; interior decoration, $524,367. On this basis 43 per cent went for outside building, 35 per cent for cemetery work, and 18 per cent for interior decoration; the remaining 4 per cent went for ornamental purposes and scattering uses, such as small ornaments, statuettes, etc.

Of the amount known to have been devoted to cemetery work, Vermont produced 81 per cent, but on the assumption that the total devoted to cemetery work was the increased figure, $1,007,709, then Vermont's percentage becomes 65.

New York supplies the largest amount for "outside building," Georgia second, Vermont third, Maryland fourth.

For interior decoration in buildings (i. e., wainscoting, tiling, mantels, washstands, etc.) Tennessee yields 57 per cent, producing three times as much for this purpose as any other one State.

There has been during the past few years a tendency in a number of marble producing States to extend the sales of marble for outside building purposes, thus creating a larger volume of business and bringing marble more definitely into competition with other kinds of stone, which for the greater part are used only for building. In times of financial distress indulgence in luxuries naturally decreases with the use of stone, as elsewhere. This brings about lower prices and reduces margins of profit. Many producers have therefore sought to offset loss of trade and profit in decorative, monumental, and cemetery products by increased sales of stone in the rough at reduced prices for structural building rather than stop quarrying altogether. This statement applies particularly to the more enterprising and determined producers, while others with less capital invested have ceased operations altogether, in some cases permanently and in others with the intention of resuming when financial conditions shall be more favorable. These statements apply with much less force to the marble industry in Vermont than to that of any other State. The great bulk of the marble output of Vermont goes into cemetery products—monuments and tombstones—and this branch of the business has grown to such proportions in the State and is of such long standing, while the stone is so well adapted to this use, that the present period of depression has simply had the effect of reducing the value of the output without compelling the leading producers to seek other uses for their product.

There is, however, another reason to explain the falling off in the total value of cemetery products, and that is the increasing competition of granite. The beauty and durability of granite, its susceptibility to fine effects in carving and polishing, and the fact that the cost of cutting, ornamenting, and polishing has become somewhat lower than formerly, are causes which have made it a formidable competitor of marble in the cemetery.

While the cost of manufacturing crude granite into monumental and ornamental stock is decidedly greater than that of producing the same effects in marble, it should be remembered that the cost of the rough granite is less also than that of such marble as is suitable for these uses. Furthermore, there is, as a rule, less elaboration in granite monuments than is expected in marble. Thus causes are at work to bring these two kinds of stone to the same plane of competition.

The popularity of marble for cemetery purposes is more pronounced in the Southern States than in the New England, Middle, and Western States. This is accounted for by a climate in the south more favorable for preservation of the stone.

Prices of Vermont marble suitable for cemetery decorative work range from \$2.25 up to \$12 per cubic foot, the last-named price being that for the grade known as statuary marble. There is a wide difference in price between crude marble and crude granite suitable for monumental work. The prices for marble have already been given. The range for crude granite for monumontal work is from 70 cents to \$1.50 per cubic foot, while for building granite the prices are from 25 to 40 cents per cubic foot.

Georgia marble for building purposes costs \$1 to \$1.25 per cubic foot.

The following table shows the purposes for which the marble of the various productive States was sold by the quarrymen:

Value of the marble product, by uses and States.

States.	Rough.	Building.	Ornamental.	Cemetery.	Interior.	Other.	Total.
California	\$4,000	....	....	....	....	....	\$4,000
Georgia	171,644	\$258,886	....	\$98,200	\$63,650	\$25,000	617,380
Idaho	1,500	....	....	4,000	....	....	5,500
Iowa	23,460	10,080	\$6,200	....	....	....	39,740
Maryland	....	109,000	....	....	1,000	....	110,000
Massachusetts	14,763	56,641	....	8,000	3,000	1,500	83,904
New York	69,072	365,737	....	41,682	4,471	3,198	484,160
Pennsylvania	3,022	28,500	....	....	....	....	31,522
Tennessee	190,103	....	....	....	190,000	1,270	381,373
Vermont	106,126	207,319	59,165	661,264	67,683	....	1,101,557
Total	583,690	1,036,163	65,365	813,146	329,804	30,968	2,859,136

The following table gives the production of marble, by States, for the years 1890 to 1896, both inclusive:

Value of marble, by States, from 1890 to 1896.

State.	1890.	1891.	1892.	1893.
California	$87,030	$100,000	$115,000	$10,000
Georgia	196,250	275,000	280,000	261,666
Idaho				4,500
Iowa				
Maryland	139,816	100,000	105,000	130,000
Massachusetts			100,000	
New York	354,197	390,000	380,000	206,926
Pennsylvania		45,000	50,000	27,000
Tennessee	419,467	400,000	350,000	150,000
Vermont	2,169,560	2,200,000	2,275,000	1,621,000
Scattering	121,850	100,000	50,000	
Total	3,488,170	3,610,000	3,705,000	2,411,092

State.	1894.	1895.	1896.
California	$13,420	$22,000	$4,000
Georgia	724,385	689,229	617,380
Idaho	3,000	2,250	5,500
Iowa		13,750	39,740
Maryland	175,000	145,000	110,000
Massachusetts		2,000	83,904
New York	501,585	207,828	484,160
Pennsylvania	50,000	59,787	31,522
Tennessee	231,796	362,277	381,373
Vermont	1,500,399	1,321,598	1,101,557
Total	3,199,585	2,825,719	2,859,136

The following is a consideration of the marble industry in each individual productive State:

California.—Although there is much fine marble in California, of great variety as to color and fineness of grain and suitable for all the purposes to which marble is put, it was in 1896 almost entirely left where nature placed it. Some concerns did a little business with stock left over from former years, but there was practically no occasion for the removal of any more from the quarries. The construction of the city hall in San Francisco called for a small amount for use in interior decoration. Some of the producers predict better conditions for 1897.

Colorado.—At the present time (March, 1897) Colorado is engaged in producing marble for use in a new public building in Denver.

Operations have been going on for some little time, but it is doubtful if any considerable amount was taken out in 1896. An interesting paper on Colorado marble, by Prof. Arthur Lakes, appeared in the August (1895) number of Stone, of which the following is a brief abstract:

The most important deposits of marble are found at the head of Yule Creek, in Gunnison County, 8 miles from the present terminus of a branch line of the Rio Grande Railroad to the anthracite coal mines, 12 miles from Crested Butte, and 32 miles from Gunnison. At the head of Yule Creek, and also on Crystal River, the Paleozoic limestones have been crystallized into white and variegated marbles. The following is the section of the marble from top to bottom of the mountain in which it occurs:

Vertical section of marble beds on Yule Creek, Colorado.

[Top, quartzites and porphyry several hundreds of feet thick.]

	Feet.
1. Pure white coarse-grained marble, very similar to but finer than that of Georgia	125
2. Pure white fine-grained statuary marble	100
3. White, with blue spots, both fine and coarse grained and soft	30
4. Pale chocolate, with green stripes, porphyry bed 8 feet thick	100
5. Dark bluish-black	40
6. White, with blue veins (like the Italian)	40
7. Delicate flesh or roseate color, with dark-green veins	10
8. Same, with dark-green blotches	2
9. Blue-gray, hard, fine grained	9
10. Flesh color or roseate and light green, mottled	30
11. Pure white statuary, very fine-grained, of Carrara quality	7
12. Variegated, a combination of many of those colors	200
13. Grass green or light green serpentine	30
Total of marbles and serpentine	723–750

The slope of débris conceals most of the underlying formations of the lower part of the mountain to its base. Here and there, however, outcrops of marble and quartzite are visible, and at the base fundamental granite, on which all these formations rest.

A remarkable feature of these marble beds is their fineness and solidity at the surface. In most districts marble is of little commercial value till a depth of several feet has been attained and the rotten superficial crust removed.

These deposits are not wholly confined to the head of Yule Creek, though the thickest and finest deposits appear to be there, but after sloping down gradually to the level of the valley and passing for awhile out of sight, the same belt reappears along Crystal River some miles distant.

No discoveries of marble in the United States have been made in recent years which disclose at once so much in favor of the material as do those in Colorado. The operations of quarrying this marble will be watched with much interest, particularly with reference to the conditions found after the surface has been well removed and the interior of the mass comes to view.

Georgia.—The marble industry of Georgia, as is evident from the table of production for different years, has developed with remarkable rapidity within the past few years. The value of the output reached its maximum in 1894 at $724,385. In 1895 this declined to $689,229, and in 1896 to $617,380. This decline is, of course, simply due to the general causes which have produced a falling off in almost every industry and is in no way to be ascribed to decline in popularity of the material. The value of the product in 1896 devoted to building is $430,530. The remainder went for cemetery use and interior decoration. In 1890 the total value of the output was $196,250, most of which was devoted to ornamental work and interior decoration. It is evident, then, that the growth of the industry in Georgia has been due to the rapidly increasing application of the material to structural or outside building rather than to increased use for interior decoration, tombstones, or ornamental products. This change in the nature of the uses to which marble is applied is not confined to Georgia, but it is characteristic of the industry in other States as well. In short, marble of certain grades is less of a luxury than it used to be. Prices have come down so that this beautiful material is within the reach of builders of all classes. Hard times have done much toward this end by curtailing, in the first place, demand for interior ornamentation, thus causing a drop in prices. This decline in price soon brought certain grades of marble to a figure which permitted a more liberal use for outside building. Producers have met the changed conditions by pushing vigorously forward in the production of building marble and in advertising its claims for recognition and adoption as a building stone in competition with other less ornamental materials. This increased use of marble for outside building constitutes what is really a new industry, and while marble will, of course, continue to be used for interior decoration and cemetery work, and in increasing amount as commercial prosperity returns, these uses will probably never again appropriate so large a proportion of the total output as formerly.

For the very best classes of marble stock, prices have been quite firmly maintained, but producers are at the same time vigorously pushing marble to the front as a building stone, and this is made possible only by reducing the price of such stone to a figure which will admit it to competition with the established building stones of the country.

Idaho.—The output of marble in Cassia County increased slightly. Most of it was used for cemetery work.

Iowa.—Production in Iowa increased to about three times the output of 1895. Most of it was sold in the rough for building purposes; none for cemetery work or interior decoration. Some of it was used for ornamental purposes.

Maryland.—The output in Maryland declined somewhat in 1896, owing to the general depression of trade.

Massachusetts.—The output in Massachusetts increased quite decidedly in 1896. This was largely due to the operations of a number of new firms which began quarrying during the year. The marble of this State has an established reputation for building, to which purpose most of the product is devoted. The reader's attention is called to a description of Westfield serpentine marble under the heading "New discoveries" in this report.

New York.—The value of the marble quarried in 1896 was $484,160, a figure more than twice as large as that for 1895. Most of the product was used for building purposes and came from Westchester County, although smaller amounts were obtained in St. Lawrence, Dutchess, Warren, Columbia, and Madison counties. New York produced more marble for outside building in 1896 than any other State; most of the increase was due to larger operations at Tuckahoe.

Pennsylvania.—Montgomery and Chester counties yielded an output valued at $31,522; much of the product is used for outside building; operations in Chester County have extended but little beyond the initial stages. This stone (Avondale marble) is a hard dolomite, not quarried with ease, but highly serviceable on account of its hardness and capability of withstanding the actions of acids. This marble has been described in a former report. The marble from Montgomery County is well known to the trade and has been quarried for many years.

Tennessee.—It is evident from the table of "uses to which marble is put," already given, that in the amount of marble devoted to interior decoration in buildings, Tennessee stands far in the lead of any other State. In the past this application of the marble output of the State has been the leading one ever since the use of marble in the manufacture of furniture, table tops, etc., went out of fashion. Now, however, the grade of stone designated "Knox pink" is becoming known as building material, and its merits for such use are claiming considerable attention from consumers of building marble. During 1894 and 1895 an investigation of Tennessee marble with special reference to its use as an outside building material was made at the engineering laboratory of the University of Tennessee. Crushing strength tests were made upon 1-inch cubes, sawed and sand-rubbed and placed between hard cardboard cushions. The table on the next page gives the results of these tests. No difference could be detected in crushing strength when the load was applied perpendicular to the bedding and when parallel to it.

Physical tests of Tennessee marble.

No. of sample.	Description of marble.	Number of samples broken.	Crushing load.	Remarks.
			Lbs. per sq. in.	
1	A light pink marble, with few traces of fossils, and nearly white when tool-dressed or sand-rubbed.	4	16,500	
2	Dark-pink marble from same quarry as No. 1, but taken from a higher stratum.	2	13,750	A fair sample of a grade of marble suitable only for interior decoration.
3	Light-gray marble with dark-blue lines nearly free from fossils.	5	17,000	A fair sample of a well-known marble.
4	Dark variegated marble, of chocolate color, with fossils well defined and abundant.	6	17,600	A much higher test than can be expected from the dark variegated marbles as a class.
5	A dark variegated marble but recently opened.	4	16,150	This was the only sample tested that showed any well-defined bedding.
6	An average sample of dark variegated marble so much used for interior work a few years ago.	4	14,400	
7	A light-colored marble, gray and pink, uniform in color, fossils well defined and abundant.	8	18,100	

The following tests to determine absorptive capacity were made. The samples were first weighed when they came to the laboratory as a check to subsequent work. They were then heated to a temperature ranging from 212° F. to 275° F. and weighed each day until the weight became constant. They were then placed in water and weighed daily until the weights again became constant.

The following table gives the results of absorption tests:

Absorption tests of Tennessee marble.

No. of sample.	Weight dry, in grams.	Weight after immersion.	Gain in weight.	Parts by weight of stone for 1 part of water absorbed.	Per cent of gain.	Remarks.
1	42.70	42.735	.035	1 in 122 ...	0.00082	
2	44.20	44.275	.075	1 in 600 ...	.0017	This result is so far from the average that it seems hardly credible.
3	43.54	43.57	.03	1 in 1,240..	.0008	
4	43.15	43.19	.04	1 in 1,100..	.00093	
5	46.53	46.53	.00	Less than 1 in 8,000.	.0000	This result also seems hardly credible.
6	53.48	53.525	.045	1 in 1,070..	.00093	
7	44.63	44.655	.025	1 in 1,480..	.00069	

The following table gives the results of an analysis of an average sample from four large blocks of Hawkins County variegated marble by Dr. Albert L. Colby, of the School of Mines, New York City:

Analysis of Hawkins County marble.

	Per cent.
Moisture	0.125
Silica, SiO_2	.125
Sesquioxide of iron, Fe_2O_3	.260
Alumina, Al_2O_3	Trace.
Lime, CaO	55.320
Magnesia, MgO	.021
Carbon dioxide, CO_2	43.510
Sulphur	.005
Organic matter and loss	.634
Total	100.000

This analysis shows the stone to be a very pure carbonate of calcium.

The following table gives the results of an independent set of tests of crushing strength, made by the Riehle Bros. Testing Machine Company, of Philadelphia, in May, 1895:

Crushing-strength tests of Tennessee marble.

Name of sample.	Size in inches.	Broke at pressure in pounds.
Pink Tennessee	2.011 x 2.009 x 2.011	63,160
White Tennessee	2.013 x 2.014 x 2.012	68,850
Do	2.013 x 2.003 x 2.013	65,400
Do	2.014 x 2.015 x 2.013	59,250

The low absorption shown by Tennessee marble shows that it is not liable to stain from coloring matters brought into contact with it.

There is a wide difference in price between the marble devoted to building purposes and that suitable for fine interior work or monumental purposes.

Material which is taken out in blocks too small to saw goes to the dump unless utilized for building, burning into lime, road metal, or railroad ballast. These blocks are just as well adapted to outside building as any of the material taken from the quarry, and consequently building marble may be sold at a low figure and is thus able to compete on the basis of price with comparatively inferior kinds of stone. There seems to be no good reason why Tennessee marble should not achieve success in its application as a building stone in competition with marble from other localities which devote the bulk of their output to outside building.

Production in 1896 amounted to a valuation of $381,373; this figure is a gain of $19,096 over 1895. About half of this valuation represents stone sold in the rough. The purposes for which the stone thus sold was used can not be certainly ascertained, but doubtless much of it was applied to building. It seems reasonable to expect that in the course of a few years Tennessee marble will have become generally known as a building stone.

Vermont.—The value of the marble output in 1896 was $1,101,557; the figure for 1895 was $1,321,598. It is evident that there has been a decline, but as decrease in production of almost everything in the line of mineral products for the last few years has been the rule, this result in the case of marble will cause no surprise.

Of the total output, 60 per cent was devoted to cemetery work, while the remainder was divided between what was sold "in the rough," for "building," for "interior decoration," and for "ornamental work."

The marble of Vermont covers a wide range of qualities, from fine statuary marble to grades sold only for outside building. That produced at West Rutland and in its vicinity is as yet without a peer in the United States for the finest uses to which marble is applied, and it supplies a large proportion of the stock used for cemetery work in the United States. Much is said from time to time in regard to new discoveries of "fine statuary marble" in one locality or another in the United States, but to find an outcropping of good white marble is one thing, and to prove that the marble is obtainable in large quantities, free from serious flaws, and susceptible of fairly economical quarrying, is another. Marble can hardly be said to have been discovered until much money has been spent in opening it up so as to reveal the character of that beneath the surface as well as its probable extent and accessibility. To make a success of marble quarrying means compliance with a variety of conditions, many of which are problematical at the outset and can only be ascertained at the expense of time and money.

Vermont is likely to remain in first place for production of fine marble for many years to come in spite of claims to superior product which are occasionally made in connection with new discoveries elsewhere. Fine white marble will always be in demand and will always command a high price, both on account of its beauty and its rarity. The increasing use of granite in cemetery work and its competition with marble in this application is discussed elsewhere in this report.

The following tabular statement shows the nature of the successive layers of marble in a quarry at West Rutland:

Section in marble quarry at West Rutland, Vermont.

	Feet.
Top, blue	20
Top, white	
Green stripe	2
Thin statuary	3–6
Striped monument	2–6
Statuary	3–6
Average layer, half green, half white	4
Brocadilla	2.6–3
Crinkly (siliceous; half light, half dark)	2–3
Light, Smith; Mottled, Smith — Light; nearly pure white	4–6
Jackman layer (6 in. green striped, 2 ft. 6 in. white)	3
Sherman (half dark green, half white)	3–6
Italian blue	15–20
Mottled limestone, of no value	

The following analyses show the composition of marble quarried at West Rutland and Proctor:

Analyses of marble from West Rutland, Vermont.

	Blue.	White.	Statuary.
	Per cent.	*Per cent.*	*Per cent.*
Insoluble	0.28	0.40	0.70
Carbon dioxide	43.82	43.66	43.65
Lime	55.27	55.26	55.50
Magnesia	.28	.15	Trace.
Iron and alumina	.30	.20	.15
Total	99.95	99.67	100.00

It is interesting to note the slight difference that there is between the blue and the white. The following two additional analyses were made by Mr. J. N. Harris:

Additional analyses of marble from West Rutland, Vermont.

	Blue.	White
	Per cent.	*Per cent.*
Silicate of alumina	0.22	0.62
Carbon dioxide	44.00	43.80
Lime	55.15	54.95
Magnesia	.57	.59
Organic matter	.05	....
Total	99.99	99.96

Analysis of marble from Proctor, Vermont.

	Per cent.
Insoluble	0.35
Carbon dioxide	44.02
Lime	55.00
Magnesia	.25
Iron and alumina	.20
Total	99.82

Additional analyses of marble from Proctor, Vermont.

	Light.	Dark.
	Per cent.	*Per cent.*
Calcium carbonate	96.30	98.37
Magnesium carbonate	3.06	.79
Iron carbonate	.053	.034
Insoluble	.63	.63
Organic matter	.004	.08
Manganese oxide	....	.005
Total	100.047	99.909

NEW DISCOVERIES.

Within the past few years there has been considerable activity among trade journals in calling attention to new discoveries of marble. Unfortunately many of these newly found sources are handicapped by difficulties in transportation. There are many sources of fine marble in the United States which are not utilized simply because the product can not yet be carried to the consumers. This is the case with a number of localities in Virginia and also in Colorado, Utah, and other Western States. It is apparently much more difficult to find ways and means of carrying marble from known sources hitherto unworked than to find still more new sources subject to the same limitations in regard to transportation. Considerable expense is involved in opening up a marble quarry and in demonstrating the applicability of the product to one or another of the various uses to which marble is applied. A certain amount of such pioneer work must, however, be done before a railroad company will extend its lines to accommodate the new enterprise, which must be able to show not only a product of fine quality but in large quantity as well. Unqualified success has attended the marble operations of Vermont, Tennessee, New York, and Georgia quarries, but much money and time have been expended in making these regions what they are to-day. Numerous financial failures mark the progress which has been made in these States, and the progress made by the successful has been attained by dint of expert knowledge of marble quarrying, unlimited perseverance, and ability to command the investment of money. Marble quarrying seems to have for the uninitiated the same kind of attraction in less degree that gold mining presents. The discovery of a new source of marble is very apt to be looked upon as inevitably meaning a large fortune for someone. While in former times there may have been good reason for such an attitude toward the production of marble, it is certainly not so justifiable at present, when prices for finished stock have been declining, and where success depends more and more upon financial resources, knowledge of quarrying and manufacturing, and the ability to command good transportation facilities.

Arizona.—White and colored marbles have been found in the Santa Rita Mountains in Arizona. The Tucson Marble Works, of Tucson, expect to operate quarries in this deposit.

Idaho.—Mr. R. S. Spence, of Paris, Idaho, has furnished the following information in regard to newly discovered marble in the vicinity of Paris:

The deposit is of large extent, varying in quality in different localities, and also in color. The colors are jet black, black with streaks of white, black and red, black and gold, and dark blue with gold markings. In one place a vein of onyx, 20 feet wide, runs through the mass. Blocks of any desirable size may be obtained, and apparently without flaw. Abundant water power is at hand. Efforts are being made to develop the property.

Massachusetts.—A combination of serpentine and marble, known as serpentine marble, occurring at Westfield, Mass., has been investigated and described by Prof. W. O. Crosby, of the Massachusetts Institute of Technology. The material is in possession of the Westfield Marble and Sandstone Company, of Westfield. The following is an abstract of Professor Crosby's report. The marble outcrops on one of the higher terraces on the south side of Little River, in the vicinity of West Parish, and only a short distance west of the boundary between the Triassic sandstone formation and the crystalline schists and granite. The deposit is closely parallel with the inclosing schists trending north-south with a vertical dip, and it is, mainly at least, of the same geologic age.

The deposit divides naturally into two parts, which are very distinct in character and origin:

1. A dike, nearly 50 feet wide, of dark-green to black serpentine.

2. On the east side of the serpentine dike, and in close contact with it, is a bed, some 75 feet thick, of gray to white crystalline marble, which is serpentine throughout. This bed of marble was originally a bed of impure limestone. During the metamorphism of the rocks of this region the limestone was changed to marble, and its impurities crystallized in the forms, chiefly, of tremolite (white) in the western

part of the bed, and actinolite (green) in the eastern part. The tremolite was very finely and the actinolite rather coarsely crystalline, in slender prismatic forms. The great dike of serpentine must have been originally a very coarsely crystalline basic rock, consisting largely of hypersthene or some related mineral. During the alteration of the dike to serpentine the tremolite and actinolite in the adjoining bed of marble have also been changed to serpentine, the former largely and the latter almost wholly. The first process of metamorphism changed the original limestone into an ordinary gray marble, similar to that of scores of other deposits throughout New England; but the second process of metamorphism, when the accessory tremolite and actinolite were serpentinized, has added great interest, beauty, and value to the deposit, and given it a highly unique character.

The quarry which has been opened in the marble gives the following section, from west to east:

Section of a marble deposit at Westfield, Massachusetts.

	Feet.
1. Massive black and green serpentine (dike)	45
2. Finely crystalline white tremolite	5
3. Serpentinic and laminated gray marble (verd antique), with several thin partings of shaly material, about	11
4. Serpentinic gray marble (verd antique), not so much laminated and without definite partings	39
5. Massive serpentinic marble (spangled)	23
Total	123

In the quarry, the western border of the deposit appears to lie directly against a solid vertical wall of schist and coarse granite (pegmatite), which would be a very favorable condition in deep working. But on the east side there are several alternations of soapstone and actinolite with schist and pegmatite for a breadth of about 25 feet before the solid formation of schist and pegmatite is reached.

With the exception of the bed of tremolite (No. 2) and the shaly partings in No. 3, the entire section, aggregating fully 115 feet, is valuable marble. The most remarkable feature of this deposit is the fact that it embraces three entirely distinct varieties of serpentinic marble, each of great beauty and interest, and each forming a solid bed of ample thickness for convenient and economic working. These varieties are:

1. Massive black and green serpentine, forming the great dike, 45 feet thick, on the west side of the quarry.

2. Variegated or veined and mottled gray and green verd antique, 50 feet thick.

3. Massive black and gray spangled marble, 23 feet thick.

1. Massive black and green serpentine marble. This variety would be a valuable marble, even if it were simply a plain black; but its beauty and interest are greatly enhanced by the bright green spots or ocelli of marmolite (a foliated form of serpentine). These vary in diameter from about one-fourth to three-fourths of an inch, being smallest

and most irregular near the borders of the dike. This marble polishes well, and it is not only strikingly rich and handsome, but is practically unique, being matched by no marble now in use. Furthermore, this dike of serpentine is thoroughly massive and solid in structure, so that blocks of almost any form or size can readily be obtained, and it is so free from the flaws and blind seams which are the bane of most serpentine marbles that it can be safely worked and used in almost any form, from thick columns to thin slabs. It will probably be found best adapted, however, for columns, pilasters, pedestals, etc. Its appearance in the natural ledges and bowlders is so sound and satisfactory that the writer is led to believe that it will also give good results in exterior work, although that is a crucial test for a serpentinic marble.

2. Laminated gray and green verd antique marble. This bed has a total thickness of about 50 feet, and the structure throughout is distinctly laminated or stratified in vertical north-south planes. The laminæ are thinnest in the western part of the bed, and, as already noted, several thin layers in the western quarter of the bed are of a somewhat shaly character. But the eastern three-quarters seems to be quite solid, so that sound blocks of almost any desired size can probably be obtained. This variety consists of a crystalline light-gray to white dolomite marble, mottled, clouded, and veined with light and dark green serpentine. When viewed edgewise it can be seen that the serpentine is to a large extent interlaminated in thin layers or patches with the dolomite, giving rise to a more or less distinct striping or banding, which must prove an attractive feature of the marble. But on surfaces parallel with the lamination it presents instead, as noted, mottled, clouded, and veined effects in endless variety and marked beauty. The colors, though bright, are soft and blending. This marble, like the others, can be used successfully in any form, but the writer anticipates that it will be wanted chiefly in the form of slabs for interior work, and then a choice will be presented between the laminated or banded and the mottled or veined verd antique. This marble resembles very closely certain phases of the celebrated Connemara marble of Ireland, but it is in the writer's opinion superior to the foreign marble in both strength and beauty.

3. Massive black and gray spangled marble. This marble is the most unique of all. The matrix or body is the same crystalline light-gray to white dolomite as in the second variety, except that the structure is in the main very massive and not distinctly laminated. This gray base or ground was originally thickly set or completely spangled with slender crystals of actinolite from 2 to 5 inches long, which are now all changed to black serpentine. Although distinctly green tints are wanting, this marble belongs, in competition, with the verd antiques. It is not unlike in general effect some of the black and white breccia marble, but spangled marble best expresses its most characteristic feature. The serpentine crystals (pseudomorphs) are set at all angles, and so closely as to form in general a complete network. But sometimes a marked

radial symmetry may be observed, and other interesting and beautiful figures. This marble, like both the others, takes an excellent polish, and its strength and massive character render it available for use in all forms, from columns a yard in diameter to the thinnest slabs. In fact, it is so free from joints and seams that blocks of any size up to the full width of the bed (23 feet) can be obtained.

The massive black and green serpentine marble is essentially pure serpentine (hydrous silicate of magnesia), and certainly contains no ingredient which would be likely on exposure to prove detrimental to its appearance or durability. The verd antique and spangled marbles are more variable in composition, since they are mixtures, in constantly varying proportions, of serpentine and gray marble. This gray base or matrix appears to be the same for both varieties, and the fairest way of getting at the composition of these varieties seemed to be to select for analysis a sample of the gray matrix as free as possible from serpentine. The appended analysis, made by Prof. Arthur A. Noyes at the Massachusetts Institute of Technology, shows that these marbles, apart from the serpentine, are nearly pure dolomites, and especially that they are practically free from deleterious ingredients. In other words, as regards composition, they are ideal serpentinic marbles.

Analysis of marble from Westfield, Massachusetts.

	Per cent.
Water	0.00
Silica and silicate	.20
Ferrous oxide	.41
Calcium oxide	32.77
Magnesium oxide	19.68
Carbon dioxide	46.91
Total	99.97

The following tests of the marble were made by Maj. J. W. Reilly, at the Watertown Arsenal. The compressed surfaces were faced with plaster of paris.

Compressive strength tests of Westfield marble.

No. of test.	Dimensions.			Sectional area.	First crack.	Ultimate strength.	
	Height.	Compressed surface.				Total.	Per square inch.
	Inches.	*Inches.*	*Inches.*	*Sq. ins.*	*Pounds.*	*Pounds.*	*Pounds.*
8779	4.05	3.73	5.60	20.89	412,000	455,800	21,820
8780	9.75	3.57	3.24	11.57	139,900	139,900	12,090

Along the north side of the quarry a mass of pegmatite partly cuts off the marble, and 250 feet south of this line a narrower mass of pegmatite divides the marble into two belts for a short distance. Between these two masses of pegmatite there is a clear body of marble 100 to 125 feet wide and 250 feet long, and this is fully exposed in the quarry for its entire breadth and about one-third of its length. Assuming an average width of only 100 feet, it is found that this body of marble contains, for every hundred feet in depth, 250 by 100 by 100 = 2,500,000 cubic feet. This amount may be regarded as reasonably certain or "in sight;" and all the geological conditions indicate an indefinite extension downward, probably hundreds of feet. The dike of black serpentine, as already noted, has been traced for a long distance north and south, but how far it is characterized by the bright green ocelli of marmolite remains to be proved. This attractive feature has nowhere been observed outside of the quarry, and, of course, its persistence in depth is not known. It can only be stated positively now that a large body of it is in sight, and that its indefinite extension downward is a fair assumption.

Utah.—The Hobble Creek Marble Company has secured 840 acres of marble property, situated at Springville, Utah County, about 8 miles from the Rio Grande, Western, and Union Pacific railways. The stone is described by Mr. Don C. Robbins as a chocolate-brown colored material containing crystals of calcite scattered through it, making a highly ornamental stone. The wagon road to the railroad is said to be an easy down grade, thus facilitating transportation to the railroad. Quarrying may be done to some extent without stripping.

The following information was furnished by Mr. J. E. Talmage, who examined the marble in the interest of the company:

The stone is a variety of concretionary limestone, and consists of a great number of concretions or nodules, globular and ellipsoidal, held together by calcareous cement. The nodules vary greatly in size, some being smaller than peas and others from 4 to 5 inches in diameter. The nodules are of a well-defined concretionary structure and in many cases show the nuclei about which the concretions have gathered. In a few instances well-preserved fossil shells are seen to form the nuclei, while in other instances the nucleus is nothing more than a grain of sand or a particle of other foreign matter not recognizable by the unaided vision. The concretions are sometimes found separate from the mass of pebbles, which, when cut, show a concretionary structure to perfection. An analysis made of one of these isolated concretions showed that 89.34 per cent of the material is calcium carbonate. The separate concretions and the massive stones are susceptible of a very high polish, and in a polished condition present a very beautiful appearance. The stone is comparatively free from ingredients such as would interfere with use for ornamental and building purposes, and is considered to be well adapted to such uses. It is of medium hardness, and therefore the labor of cutting and polishing will not be great; on the other hand, it is sufficiently hard to resist ordinary causes of injury. The stone occurs in extensive, well-defined ledges, compact, and while varying greatly in appearance, owing to the unequal distribution of the concretions, the formation affords very large masses of comparatively homogeneous material. The supply is practically inexhaustible, while the ready accessibility of the deposit and its proximity to a railway promise great results from an intelligent working of the formation.

West Virginia.—Marble has been discovered in Pocahontas County, West Virginia. The stone is in part dove colored, white mottled, and with dark veins. Variegated stone is also abundant, running from red to maroon. The stone is fossiliferous in character so far as the examination has gone, but as yet no cores running to considerable depth have been reported upon. Five or 6 miles are exposed to view and covered by little débris; the bed is said to be 40 feet thick and nearly horizontal. The property has been examined by Mr. George C. Underhill, a marble expert of Rutland, Vermont. As seems to be generally the case with a newly discovered marble bed, railroad facilities are lacking.

SLATE.

The following table shows the output of roofing and milled slate in 1896:

Value of slate product in 1896, by States.

State.	Roofing slate.		Other purposes, value.	Total value.
	Squares.	Value.		
Georgia	4,597	$20,388		$20,388
Maine	23,078	99,831	$24,255	124,086
Maryland	15,557	70,194	1,948	72,142
Massachusetts			1,200	1,200
New Jersey	200	700		700
New York	16,002	78,612	3,880	82,492
Pennsylvania	431,324	1,391,539	334,779	1,726,318
Tennessee	160	640	780	1,420
Vermont	155,523	509,681	99,915	609,596
Virginia	26,863	92,163	15,700	107,863
Total	673,304	2,263,748	482,457	2,746,205

A comparison of these figures with the corresponding totals for 1895 shows a gain of $47,505 in value of total output, a gain of $135,266 in the value of milled stock, a loss of $87,761 in the value of roofing slate, and a loss of 56,623 squares of roofing slate.

The following table shows the average value of roofing slate per square since 1890:

Average annual price per square of roofing slate for the entire country.

1890	\$3.34	1894	\$3.11
1891	3.49	1895	3.23
1892	3.56	1896	3.36
1893	3.55		

The price per square has evidently risen about as much above that for 1895 as the latter exceeds the figure for 1894.

The industry as a whole has done exceedingly well considering the persistence of hard times. This would not have been the case had it not been for the appearance of what to all practical purposes is a new feature in the slate industry, namely the export trade. Attention was attracted to the export movement in the early part of the year, but its activity increased until in July some notably large shipments were made to England, Germany, and other countries. Much of the slate sent to England was reshipped to Australia and South America.

This roundabout way of reaching the consumers in the last-named countries has been quite freely discussed in some of the trade journals, and the advisability of dealing direct with the foreign users of slate is so apparent that it is not unreasonable to look for a readjustment of trade relations by which so much unnecessary transportation of the slate may be avoided. Exportations have not been confined to roofing slate, but have included blackboards in notable quantity and to some extent other milled products.

The cause of this rather sudden advance in exportation is in part the labor troubles and strike among the slate quarrymen of Wales. As a result of partial suspension of work in the Welsh quarries and their consequent inability to fill orders, the United States consuls in foreign parts were in a few instances called upon early in 1896 to furnish lists of United States slate exporters. As a result negotiations with American producers were soon under way, agents being sent abroad to receive orders, while foreign purchasers from England, Wales, and Germany made their appearance in our own slate markets. Our slate seems to have given satisfaction abroad, and the troubles at the Welsh quarries have given producers in this country such an opportunity to display their products and secure trade as might have been much longer withheld under normal conditions. It is to be hoped that the trade thus secured by reason of temporary conditions may be held by virtue of the quality of our product and the business enterprise and sagacity of our producers.

Some difficulty with steamship companies on the question of privilege to ship slate in bulk rather than in crates was at first experienced, but this was finally overcome. The expense of crating was a very serious item and had been almost prohibitory to exportation, so that the advantage of shipment in bulk is one of considerable moment.

The following table shows the value of the production of slate, by States, during the years 1890 to 1896, inclusive:

Value of slate, by States, from 1890 to 1896.

State.	1890.			
	Roofing slate.	Value.	Other purposes than roofing, value.	Total value.
	Squares.			
California	3,104	$18,089		$18,089
Georgia	3,050	14,850	$480	15,330
Maine	41,000	201,500	18,000	219,500
Maryland	23,099	105,745	4,263	110,008
New Jersey	2,700	9,675	1,250	10,925
New York	16,767	81,726	44,877	126,603
Pennsylvania	476,038	1,641,003	370,723	2,011,726
Vermont	236,350	596,997	245,016	842,013
Virginia	30,457	113,079		113,079
Other States *a*	3,060	15,240		15,240
Total	835,625	2,797,904	684,609	3,482,513

State.	1891.			
	Roofing slate.	Value.	Other purposes than roofing, value.	Total value.
	Squares.			
Arkansas	120	$480		$480
California	4,000	24,000		24,000
Georgia	3,000	13,500		13,500
Maine	50,000	250,000		250,000
Maryland	25,166	123,425	$2,000	125,425
New Jersey	2,500	10,000		10,000
New York	17,000	136,000	40,000	176,000
Pennsylvania	507,824	1,741,836	401,069	2,142,905
Vermont	247,643	698,350	257,267	955,617
Virginia	36,059	127,819		127,819
Other States *a*				
Total	893,312	3,125,410	700,336	3,825,746

a Includes Arkansas, Michigan, and Utah.

Value of slate, by States, from 1890 to 1896—Continued.

State.	1892.			
	Roofing slate.	Value.	Other purposes than roofing, value.	Total value.
	Squares.			
California	3,500	$21,000	....	$21,000
Georgia	2,500	10,625	....	10,625
Maine	50,000	250,000	....	250,000
Maryland	24,000	114,000	$2,500	116,500
New Jersey	3,000	12,000	....	12,000
New York	20,000	160,000	50,000	210,000
Pennsylvania	550,000	1,925,000	408,000	2,333,000
Vermont	260,000	754,000	260,000	1,014,000
Virginia	40,000	150,000	....	150,000
Total	953,000	3,396,625	720,500	4,117,125

State.	1893.			
	Roofing slate.	Value.	Other purposes than roofing, value.	Total value.
	Squares.			
Georgia	2,500	$11,250	....	$11,250
Maine	18,184	124,200	$15,000	139,200
Maryland	7,422	37,884	....	37,884
New Jersey	900	3,653	....	3,653
New York	69,640	204,776	206	204,982
Pennsylvania	364,051	1,314,451	157,824	1,472,275
Utah	75	450	400	850
Vermont	132,061	407,538	128,194	535,732
Virginia	27,106	104,847	12,500	117,347
Total	621,939	2,209,049	314,124	2,523,173

Value of slate, by States, from 1890 to 1896—Continued.

State.	1894. Roofing slate.	Value.	Other purposes than roofing, value.	Total value.
	Squares.			
California	900	$5,850		$5,850
Georgia	5,000	22,500		22,500
Maine	24,690	123,937	$22,901	146,838
Maryland	39,460	150,568	2,500	153,068
New Jersey	375	1,050		1,050
New York	7,955	42,092	2,450	44,542
Pennsylvania	411,550	1,380,430	239,728	1,620,158
Vermont	214,337	455,860	202,307	658,167
Virginia	33,955	118,851	19,300	138,151
Total	738,222	2,301,138	489,186	2,790,324

State.	1895. Roofing slate.	Value.	Other purposes than roofing, value.	Total value.
	Squares.			
California	1,500	$10,500		$10,500
Georgia	2,500	10,675		10,675
Maine	23,774	118,791	$21,363	140,154
Maryland	13,188	59,157	1,200	60,357
New Jersey	200	700		700
New York	13,624	90,150	1,725	91,875
Pennsylvania	426,687	1,437,697	210,054	1,647,751
Vermont	221,359	531,482	93,849	625,331
Virginia	27,095	92,357	19,000	111,357
Total	729,927	2,351,509	347,191	2,698,700

Value of slate, by States, from 1890 to 1896—Continued.

State.	1896.			
	Roofing slate.	Value.	Other purposes than roofing, value.	Total value.
	Squares.			
Georgia	4,597	$20,388	....	$20,388
Maine	23,078	99,831	$24,255	124,086
Maryland	15,557	70,194	1,948	72,142
Massachusetts	....	....	1,200	1,200
New Jersey	200	700	....	700
New York	16,002	78,612	3,880	82,492
Pennsylvania	431,324	1,391,539	334,779	1,726,318
Tennessee	160	640	780	1,420
Vermont	155,523	509,681	99,915	609,596
Virginia	26,863	92,163	15,700	107,863
Total	673,304	2,263,748	482,457	2,746,205

THE SLATE INDUSTRY IN THE VARIOUS STATES.

California.—The slate quarries of this State were shut down for the entire year on account of a lack of demand. Revival of general prosperity will doubtless result in a resumption of productive operations. The slate is of good quality, but has to compete with the excellent redwood shingles of the State, and naturally in hard times the cheaper material prevails. The producers state that they expect to operate during 1897.

Georgia.—The output in Georgia is an increase over that of 1895. A new firm, or rather an old one revived, will in 1897 add its efforts to those of the already existing concerns. The average price per square increased from $4.27 in 1895 to $4.43 in 1896.

The following is an analysis of Georgia slate, from the quarry of the Georgia Slate Company, at Rockmart, made by Messrs. J. W. Slocum and H. H. Van Deventer, of Knoxville, Tennessee.

Analysis of Rockmart slate.

	Per cent.		Per cent.
Silica	58.20	Carbonic acid	.60
Alumina	18.83	Sulphur	.49
Protoxide of iron	5.78	Water	4.07
Lime	4.35	Titanic acid	.10
Magnesia	3.51	Lithia	.02
Potassium oxide	2.51	Oxide of manganese	Trace.
Sodium oxide	.69	Total	99.97
Carbon	.82		

If all that is now contemplated in the way of developing the Rockmart slate is actually carried out, the industry in this State should make itself felt over a much wider area of the country than it affects at present. Sixty thousand dollars have already been invested in one of the enterprises, resulting in thoroughly stripping the face of one of the older quarries, which is in condition now to yield slate without much more preliminary work. Preparations for the erection of a mill for making switch boards are under way. It is claimed, as the result of tests made at Columbia College, New York, that Georgia slate is excellent in its nonconducting power for electricity, and is therefore valuable for the manufacture of switch boards. A comparison of the results of chemical analyses of Georgia and Peach Bottom slates shows them to be quite similar in composition.

Maine.—Operations in Maine were less active than in the preceding year. The slate of this State is of fine quality and always commands a good price.

Maryland.—The output shows a slight increase in amount and in average value per square. This was \$4.48 in 1895 and \$4.51 in 1896. All the Maryland slate comes from the northern part of Harford County, and the quarries are all in what is known as the Peach Bottom region, which extends into York County, Pennsylvania.

The following analysis was made by Messrs. Booth, Garrett, and Blair, of Philadelphia:

Analysis of the Peach Bottom slate.

	Per cent.		Per cent.
Silica	58.370	Carbonic acid	.390
Protoxide of iron	10.661	Carbon	.930
Alumina	21.985	Water	4.030
Lime	.300	Titanic acid	Trace.
Magnesia	1.203	Oxide of manganese	Trace.
Alkali	1.933	Total	99.909
Sulphur	.107		

The following test was made by Prof. L. E. Reber, of State College, Pennsylvania:

The first specimen, with pressure applied parallel to natural cleavage, fractured at 22,000 pounds and crushed at 48,200 pounds.

Second specimen, pressure applied perpendicular to the natural cleavage, fractured at 41,000 pounds and crushed at 94,800 pounds. The first specimen crushed at 385.6 tons per square foot. The second specimen crushed at 758.4 tons per square foot. The specimens used were 3-inch cubes.

At the end of the present chapter on slate will be found an abstract of a paper by Prof. Mansfield Merriman, of Lehigh, read before a meeting of the American Society of Civil Engineers on December 19, 1894. In this paper valuable data on slates of Cambrian and Silurian origin are presented. Peach Bottom slate is taken as typical of Cambrian slate, and the reader is therefore referred to this abstract for additional data respecting Maryland slate.

Massachusetts.—This State makes its first appearance in these reports as a slate-producing State, although the existence of slate within its borders has long been known, and small amounts of slate have been produced from time to time within recent years.

The following is a statement of the results of analysis of slate from Lancaster, Worcester County:

Analysis of Worcester County slate.

	Per cent.
Silica, SiO_2	60.80
Alumina, Al_2O_3	22.00
Magnesia, MgO	.70
Ferric oxide, Fe_2O_3	10.50
Water	1.80
Calcium oxide, CaO	.50
Potassium oxide, K_2O	1.50
Sodium oxide, Na_2O	.80
Carbon	.80
Total	99.40

Minnesota.—This State does not appear in the tables as producing slate and as yet it produces none, but good material has been found in Carlton County and is now being investigated, with favorable results so far as experiments have gone. About 200 squares have been disposed of locally. A sample examined by the writer shows excellent cleavage and permanent color. Cleavage is nearly vertical. Ribbons occur in the surface slate, but disappear with increasing depth. The slate is adapted to blackboard use as well as to roofing. Transportation facilities are at hand, and there is no reason thus far apparent why quarrying operations in times of average prosperity should not be profitable.

New Jersey.—The New Jersey slate is a continuation of the Pennsylvania slate belt, and the quarries are not far from the State line. As is evident from the tables, but little has been done during the past year.

New York.—The slate output of New York is of special interest, because it includes the only cherry-red slate produced in the United States. On account of its unique color and its scarcity, even in New York State, it commands the highest price of any of the slates in the United States. The total value of the output in 1896 was $82,492. Of this amount $78,612 represented the value of 16,002 squares of roofing slate; 7,502 squares were of red slate, valued at $57,412, and the remainder was purple or green slate of the same general character as much of the slate quarried in Vermont.

The following data relative to New York and Vermont slate are of interest and were the result of experiments by Mr. J. Francis Williams, C. E. One-inch cubes were used.

Compressive and flexural tests of New York and Vermont slates, in pounds per inch.

	Purple.	Red.	Green.
Compressive strength, wood cushions	19, 380	14, 170	13, 140
Compressive strength, pasteboard cushions	27, 760	18, 110	17, 560
Compressive strength, no cushions	13, 860	10, 190	8, 040
Elastic limit, no cushions	10, 260	4, 850	5, 150
Modulus of rupture	10, 800	7, 310	8, 840

Pennsylvania.—Pennsylvania produced slate amounting to about 63 per cent of the total output of the whole country. An increase in product over 1895 is evident from the tables.

The following table shows the distribution of the output among the various productive counties:

Output of slate in Pennsylvania in 1896, by counties.

County.	Roofing slate.	Value.	Other purposes, value.	Total value.
	Squares.			
Carbon	4, 000	$12, 000		$12, 000
Lehigh	103, 955	350, 020	$153, 948	503, 968
Northampton	317, 842	1, 005, 281	180, 831	1, 186, 112
York	5, 527	24, 238		24, 238
Total	431, 324	1, 391, 539	334, 779	1, 726, 318

A quite decided advance in the production of milled stock is apparent, as are also the effects of the increased export trade; in fact, but for this there would have been a decline in output as compared with 1895. Pennsylvania received most of the benefit of the increased exportation. Replies from many if not a majority of the Pennsylvania producers stated that domestic business was poor. Some, however, claimed that this deficiency was offset by the advance in the export trade. The increase in the production of milled stock is probably due to greater activity in the manufacture of blackboards, which contribute quite materially to the stock exported.

The following is an analysis of Bangor slate by Mr. Henry Leffman, of Philadelphia:

Analysis of Bangor (Northampton County) roofing slate.

	Per cent.
Silica	68.620
Iron oxide	4.200
Alumina	12.680
Calcium carbonate	2.337
Magnesia	3.759
Alkalies	3.730
Moisture and combustible matter	4.470
Total	99.796

Tennessee.—Slate has been known to exist in Tennessee for a long time, but systematic efforts to quarry it are of recent date.

The operated quarries are at Chilhowee, Blount County. The producing firm is the Tennessee Slate Company, with headquarters at Chattanooga. The quarries are at the junction of the Tennessee River and Abrams and Panther creeks. Water power is abundant. Two quarries are in operation, and a mill containing two planers, two saws, and one rubbing bed; facilities will be increased as business expands.

Director Charles D. Walcott, of the United States Geological Survey, has personally studied this locality and says that "when the layers of bedding coincide with those of cleavage the slates are of fine quality, even where the rock is of sufficiently varied composition to produce ribbons. The durability of the material is well shown by the cliffs along the river, which have stood the wear for centuries."

Vermont.—Vermont stands second in output of slate, producing a little more than two-thirds as much as Pennsylvania. The export trade benefited Vermont quite materially during the past year, although the total valuation falls below that of 1895. This benefit showed more for milled slate than for roofing. The slate of Vermont differs fundamentally from Pennsylvania slate in color, that of Pennsylvania being black, or nearly so, while the Vermont material is of various shades of purple and green. Recently, however, black slate has been found and is being quarried by the American Black Slate Company, whose quarries and mills are at Benson, Vermont, on Lake Champlain. Future developments of the black slate will be awaited with interest.

Virginia.—The productive quarries are at Arvonia, in Buckingham County. The output in 1896 very nearly equaled that of 1895. Business was best in the early part of the year.

TESTS OF SLATE.

The following is an abstract of a paper by Prof. Mansfield Merriman, of Lehigh. It was read before the meeting of the American Society of Civil Engineers on December 19, 1894. One of the objects of the investigation was to compare slates of Cambrian and Silurian origin by tests upon typical representatives of the two classes. The results are therefore of general as well as of special interest. The material taken as typical Cambrian slate is the Peach Bottom slate of York County, Pennsylvania, and Harford County, Maryland, while the Silurian slate is represented by that from Northampton County, Pennsylvania.

Results of experiments on the Peach Bottom slate are first presented. The specimens were 12 by 24 inches, and varied from 0.21 to 0.29 inch in thickness. For test of strength they were laid on supports 22 inches apart and broken by a load slowly applied in the middle. The modulus of rupture was determined from the formula

$$\text{Mod} = \frac{3 \times \text{breaking load} \times \text{length}}{2 \times \text{width} \times \text{square of thickness.}}$$

Toughness was measured by taking deflection in inches at moment of rupture. The degree of softness was determined by taking the weight abraded by 50 turns of a small grindstone under a constant pressure of 10 pounds. The porosity was determined by taking the percentage of water absorbed in twenty-four hours after drying for the same length of time at 135° F. The test for corrodibility was the percentage of loss of weight after immersion for sixty-three hours in a solution of 98 parts water, 1 part hydrochloric acid, and 1 part sulphuric acid. The color was dark bluish-gray or bluish-black. The texture of the surface was scaly and soapy—less smooth than Northampton varieties. When upturned by flexure the specimens broke square across the grain, without splitting or lamination.

The author states that an examination of these results tends to confirm the conclusions announced in a previous paper—that in general the strongest specimens are the heaviest and softest as well as the least corrodible, although exceptions occur in the case of specimens marked Q_7 and P_2, and the specimens marked with Q's seem more corrodible than those marked with P's, though greater in strength. The tests for strength and corrodibility are probably those of greatest value in determining the durability of the slate under actual conditions of service. The test for softness, although a good one for a single lot of specimens, may not serve to fairly compare lots tested at different times, on account of the varying conditions of the grindstone.

The following table shows the results of tests of Peach Bottom roofing slate:

Results of tests of Peach Bottom roofing slate.

Mark of specimens.	Strength—modulus of rupture.	Toughness—ultimate deflection in inches on supports 22 inches apart.	Density—specific gravity.	Softness—grains abraded by 50 turns of a small grindstone.	Porosity—per cent of water absorbed in 24 hours.	Corrodibility—per cent of weight lost in 63 hours in acid solution.
Q_1	11,490	0.32	2.886	69	0.265	0.247
Q_2	12,585	.30	2.907	115	.197	.197
Q_3	8,400	.30	2.900	110	.304	.291
Q_4	13,430	.32	2.893	177	.228	.194
Q_5	8,320	.28	2.900	75	.264	.237
Q_6	12,010	.32	2.918	67	.209	.200
Q_7	14,210	....	2.890	111	.278	.341
Q_8	13,060	.34	2.902	67	.261	.240
P_1	10,520	.24	2.912	69	.171	.150
P_2	9,360	.20	2.885	53	.143	.226
P_3	10,470	.34	2.858	87	.216	.161
P_4	11,255	.26	2.873	80	.155	....
Means	11,260	.293	2.894	90	.224	.226

The following analyses show the composition of the Peach Bottom slates:

Analysis of Peach Bottom slate by the Pennsylvania Geological Survey in 1877.

	Per cent.
Silicic acid (SiO_2)	55.880
Alumina (Al_2O_3)	21.849
Ferrous oxide (FeO)	9.034
Water (H_2O)	3.385
Potash (K_2O) and Soda (Na_2O)	4.100
Carbon (C)	1.974
Magnesia (MgO)	1.495
Lime (CaO)	.155
Sulphuric oxide (SO_3)	.022
Titanic acid (TiO_2)	1.270
Manganous oxide (MnO)	.586
Iron bisulphide (FeS_2)	.051
Cobaltous oxide (CoO)	Trace.
Total	99.801

Analysis of Peach Bottom slate by Booth, Garrett, and Blair, in 1885.

	Per cent.
Silica	58.370
Alumina	21.985
Protoxide of iron	10.661
Water	4.030
Alkali	1.933
Carbon	.930
Magnesia	1.203
Lime	.300
Sulphur	.107
Titanic acid	Trace.
Oxide of manganese	Trace.
Carbonic acid	.390
Total	99.909

The valuable constituents in slate are the silicates of iron and aluminum, while the injurious constituents are sulphur and the carbonates of lime and magnesia.

The slates of the Cambrian formation are usually better in regard to strength and weathering qualities than those of the Silurian age, the market price of some varieties of the former being, indeed, more than double that of the common kinds of the latter.

The Northampton slates take a high rank among the Silurian kinds, while the Peach Bottom specimens may be regarded as a good representation of the dark blue Cambrian varieties. The following tabulation, giving the mean results of the series of tests of both, may hence be taken as the best comparison possible at present of the average physical properties and chemical composition of the Silurian and Cambrian dark-colored slates of Pennsylvania:

Table showing relative properties of Silurian and Cambrian slates.

Property.	Measured by—	Silurian.	Cambrian.
Strength	Modulus of rupture in pounds per square inch.	8.480	11.260
Toughness	Ultimate deflection in inches on supports 22 inches apart.	.291	.293
Density	Specific gravity	2.777	2.894
Softness	Grains abraded on grindstone under stated conditions.	.1	.90
Porosity	Per cent of water absorbed in 24 hours.	.104	.224
Corrodibility	Per cent of water lost in acid solution in 63 hours.	.496	.226
Valuable constituents.	Silicates of iron and aluminum, per cent.	81.88	88.89
Injurious constituents.	Sulphur, per cent	.58	.07
	Carbonates of lime and magnesia, per cent.	12.59	3.19

With respect to the relative value of physical tests and chemical analyses, it may be said that while the latter are valuable, the former alone can be regarded as giving authoritative information as to the wear of slate under actual conditions. The strength and weathering qualities of slate or stone depends not merely upon its chemical constituents, but on the manner in which the grains are cemented together. For the determination of this a microscopic inspection is necessary, and in the absence of such the physical tests seem to carry far greater weight than the chemical analyses.

While the preceding methods of testing are readily carried on in the laboratory, they are not easily made under conditions of actual practice, on account of the absence of precise weighing apparatus and the lack of time and skill. It seems desirable that a test for slate should be devised which can be quickly applied by an architect or builder and used with confidence. An impact test made by simply dropping a ball appeared one likely to yield good results, and accordingly a series of experiments has been carried on to determine what can be done in this direction. In connection with these a series of severe acid tests has been made on the same specimens.

Seven varieties of slate were used in these experiments. Four, designated hereafter by the letters C, D, E, and F, were Silurian slates of

Pennsylvania. Three were Cambrian slates, P and Q being Peach Bottom specimens, and V being a red slate from the New York and Vermont region.

The pieces of slate used in the impact test were 6 by 7¾ inches. Each piece was placed with the ends loosely clamped in grooved supports, so that it was approximately in the condition of a beam with fixed ends, the length between edges of supports being about 7¼ inches and the width 6 inches. A wooden ball weighing 15.7 ounces was dropped upon the middle of the slate from a height of 9 inches and the number of blows required to produce rupture was noted. The number of foot-pounds of work per pound of slate expended in causing rupture is a measure of the ultimate resistance of the material or of its capacity to resist shock, and thus is an index both of its strength and toughness. Five specimens of each kind of slate were thus tested, and the following table gives the individual results and means:

Table showing comparative tests of Silurian and Cambrian slates as to resiliency.

SILURIAN SLATES.

Specimens.	Thickness (inches).	Weight (ounces).	Number of blows.	Foot-pounds of work per pound of slate.
C_1	0.21	13.8	6	5.12
C_2	.19	12.9	4	3.65
C_3	.22	13.8	5	4.27
C_4	.20	12.8	7	6.62
C_5	.23	15.6	10	7.56
Means	.21	13.8	6.4	5.44
D_1	.19	13.0	5	4.53
D_2	.22	14.5	7	5.69
D_4	.19	12.4	3	2.85
D_9	.22	14.8	7	5.58
D_{11}	.24	16.2	6	4.37
Means	.21	14.2	5.6	4.60
E_1	.19	12.4	4	3.63
E_{14}	.20	13.5	2	1.74
E_{18}	.21	13.5	4	3.50
E_{20}	.19	13.0	6	5.44
E_{19}	.22	14.3	5	4.12
Means	.20	13.3	4.2	3.68
F_2	.22	14.4	4	3.27
F_4	.20	13.3	3	2.66
F_6	.22	14.7	5	4.01
F_7	.25	16.5	7	5.00
F_8	.20	13.7	3	2.58
Means	.22	14.5	4.4	3.50

Table showing comparative tests of Silurian and Cambrian slates as to resiliency—Continued.

CAMBRIAN SLATES.

Specimens.	Thickness (inches).	Weight (ounces).	Number of blows.	Foot-pounds of work per pound of slate.
P_1	0.26	17.3	9	6.13
P_2	.26	17.2	15	10.29
P_3	.31	20.4	55	31.74
P_4	.28	18.4	52	33.35
PP_4	.29	20.4	68	39.33
Means	.28	18.7	39.8	24.17
Q_1	.26	17.2	11	7.54
Q_2	.27	17.8	20	13.25
Q_3	.29	19.3	17	10.39
Q_7	.28	18.2	6	3.89
QQ_7	.28	17.6	11	7.37
Means	.27	18.0	13.0	8.49
V_1	.21	13.0	32	29.04
V_2	.26	17.3	215	146.65
V_3	.21	12.9	339	310.09
V_4	.20	12.9	55	50.31
V_5	.25	14.2	117	97.22
Means	.23	14.1	151.6	126.66

Size of specimen, 6 by 7¾ inches.
Weight of ball, 15.7 ounces.
Height of fall, 9 inches.

The acid tests were purposely made severe in order to obtain, if possible, a better idea of the resistance to corrosion than is given by the previous test of sixty-three hours.

Seven jars containing a solution of 1 part of hydrochloric acid, 1 part of sulphuric acid, and 98 parts of water, by weight, were prepared, and two specimens of each variety of slate were immersed in each for one hundred and twenty hours, or five days, the solution being well stirred once a day. The specimens were then taken out, dried for forty hours, weighed, and the loss of original weight determined. The solution was next strengthened by adding the same amount of the two acids, and the specimens were then replaced for another one hundred and twenty hours, after which they were dried and weighed again. The solution was again strengthened by the addition of the same amount of acid, and the specimens were immersed for one hundred and twenty hours, after which they were dried and weighed as before. The specimens used for this purpose weighed about 1½ ounces each, and the scales were sufficiently delicate to detect one-half grain. With two exceptions they were parts of the pieces previously broken in the impact tests.

In the following table the percentages of loss of original weight at the end of the three periods are given, the specimens being arranged in order of corrodibility, and also in the last columns the mean foot-pounds of work per pound of slate required to cause rupture by impact and the mean specific gravities. These figures show that the specific gravity is not a good index of corrodibility, but they plainly indicate that the least corrodible slate offers the greatest resistance to impact, although there are slight exceptions in the case of D and E.

Corrodibility tests of slates by immersion in acid solutions.

Specimens.	Percentages of loss of weight.			Foot-pounds of work per pound of slate.	Specific gravity.
	After 120 hours.	After 240 hours.	After 360 hours.		
D_2	1.06	1.94	2.74		
D_9	1.22	1.94	2.79		
Mean	1.14	1.94	2.76	4.6	2.77
F_9	1.08	1.60	2.18		
F_2	1.43	2.47	2.98		
Mean	1.25	2.03	2.58	3.5	2.77
E_{18}	.82	1.36	1.82		
E_{20}	.88	1.48	2.09		
Mean	.85	1.42	1.95	3.7	2.78
C_2	.64	1.28	1.70		
C_5	.54	1.10	1.66		
Mean	.59	1.19	1.68	5.4	2.78
Q_3	.45	.90	1.27		
Q_5	.40	.99	1.32		
Mean	.42	.94	1.29	8.5	2.90
P_3	.32	.81	1.12		
P_4	.28	.93	1.10		
Mean	.30	.87	1.11	24.2	2.89
V_4	.00	.17	.34		
V_5	.00	.09	.17		
Mean	.00	.13	.25	126.7	2.81

With regard to the progress of the corrosion with time, it appears that the two are approximately proportional. A marked change in color of the Silurian specimens was noted, the dark blue becoming a grayish white after the last immersion, while but a slight change appeared in Q, and P and V remained almost unaffected. Change in color is thus a direct index of corrodibility, both being due to the same cause.

As the result of the investigations thus far made, it may be concluded that the tests for density and softness, although of importance for slates of the same locality, are not good indications of the strength and weathering qualities of those of different regions; that the tests for porosity, corrodibility, and flexual strength give good indications of these properties; that the results found for strength and corrodibility when mentally combined give, on the whole, an excellent idea of the value of the slate; and that an impact test with a wooden ball shows both strength and toughness, while it at the same time indicates the capacity for resistance to corrosion. The impact test may be therefore recommended, if only a single test is to be used, as one that can be quickly and cheaply made, and one likely to give reliable information of the comparative value of different kinds of slate.

The following matter of interest in connection with the Welsh slate quarries is taken from the American Slate Trade Journal, Bangor, Pennsylvania, issue of March, 1897.

WELSH SLATE QUARRIES.

English slates, instead of being sold by the square, are sold by the "mille," contracted into "M," which is in reality 1,200 slates. To this number is added 5 per cent for breakage, giving a standard unit of slate of 1,260 pieces. This standard is practically the one adopted in all foreign countries, and it becomes necessary for American quarrymen and dealers to familiarize themselves with this unit in order to do foreign trade.

A few of the principal sizes of slates, and the equivalent in squares of 1,260 pieces of each size, are as follows:

Principal sizes of slate in Wales.

20 × 10, M =	7 squares 43 feet.
24 × 12, M =	11 squares 3 feet.
24 × 14, M =	12 squares 86 feet.
22 × 12, M =	9 squares 97 feet.
22 × 11, M =	9 squares 15 feet.
18 × 10, M =	6 squares 56 feet.
18 × 9, M =	5 squares 91 feet.

Two of the largest slate quarries in the world are near Bangor, North Wales, and are the properties of Lord Penrhyn and George William Duff-Asheton Smith. The product of these two quarries is of excellent quality and of several colors. The quarries of North Wales yield in the aggregate something like 500,000 tons annually. There is but one slate-yielding district in Great Britain that may fairly claim distinction, i. e., the Westmoreland and Cumberland districts.

The total output of slate from the quarries in the United Kingdom for the last five years, up to and including 1895, is as follows:

Total output of slate in Great Britain, 1891 to 1895.

Year.	Tons.	Value.
1891	415, 029	£987, 000
1892	418, 241	1, 025, 922
1893	438, 993	1, 107, 626
1894	461, 673	1, 171, 366
1895	581, 760	1, 274, 146

North Wales furnishes the bulk of this, two-thirds of it from open quarries and the remaining one-third from mines or true underground excavations. Of the 581,760 tons produced during 1895, 429,419 tons came from quarries and 152,341 tons from mines. The production from quarries during 1895 of 429,419 tons was made up as follows:

Distribution of the quarry product of slate in 1895.

	Tons.
Wales	288, 000
England	76, 322
Scotland	43, 886
Ireland	10, 848
Isle of Man	10, 363
Total	429, 419

The bulk came from Wales, and out of the total of 288,000 tons 258,587 tons are produced in Carnarvonshire alone. Most of this comes from the Penrhyn quarry, the output from which in 1895 was about 100,000 tons, and the Dinorwic quarry, which produced the same year some 80,000 tons.

The imports of foreign slates during 1895 were as follows:

Imports of slate into Great Britain in 1895.

Country.	Quantity, in number of slates.	Value.
France	8,332,065	£33,074
Belgium	4,586,114	21,907
United States of America	1,587,810	11,206
Portugal	1,177,320	5,496
Holland	2,880	6
Total	15,686,189	71,689

The exports during 1895 were of the value of £176,023, and were distributed as follows:

Exports of slate from Great Britain in 1895.

Country.	Number of slates.
Germany	22,727,000
Denmark	2,323,300
Austria	1,195,200
Australasia	832,800
British South Africa	774,500
Belgium	559,500
Channel Islands	561,900
France	448,900
Argentine Republic	227,300
British Uruguay	209,500
British North America	64,500
British West Indies	51,400
Miscellaneous	67,500
Total	30,043,300

The Penrhyn quarry is the largest in the United Kingdom, producing about 120,000 tons of slate annually, besides stripping top rock and rubbish to the extent of 1,500,000 tons per annum. It is situated at Bethesda, near Bangor, and the slates are shipped to Port Penrhyn, which is only a few miles from the quarry, with which it is connected by a private line of railway. This quarry is the property of Lord Penrhyn, and is under the management of Mr. E. A. Young. At the time of writing, however, the quarry is closed in consequence of a general strike of the 3,000 workmen engaged in the quarry, owing to the suspension by the management of 71 men.

SANDSTONE.

The following table shows the output of sandstone in the United States for the year 1896:

Value of the sandstone product in 1896, by States.

State.	Value.	State.	Value.
Alabama	$48,000	Montana	$3,250
Arizona	10,000	New Jersey	126,534
Arkansas	1,400	New York	223,175
California	7,267	North Carolina	13,250
Colorado	58,989	Ohio	1,679,265
Connecticut	426,029	Pennsylvania	446,926
Georgia	1,250	South Dakota	37,077
Idaho	16,060	Tennessee	4,100
Illinois	15,061	Texas	36,000
Indiana	32,847	Utah	7,860
Iowa	12,351	Washington	11,090
Kansas	18,804	West Virginia	24,693
Maryland	10,713	Wisconsin	65,017
Massachusetts	304,361	Wyoming	16,465
Michigan	111,321	Total	4,023,199
Minnesota	202,900		
Missouri	51,144		

The value of the output in 1895 was $4,211,314. It is evident that there has been some falling off during the past year.

The following table shows the output of sandstone, by years, from 1890 to 1896:

Value of sandstone, by States, from 1890 to 1896.

State.	1890.	1891.	1892.
Alabama	$43, 965	$30, 000	$32, 000
Arizona	9, 146	1, 000	35, 000
Arkansas	25, 074	20, 000	18, 000
California	175, 598	100, 000	50, 000
Colorado	1, 224, 098	750, 000	550, 000
Connecticut	920, 061	750, 000	650, 000
Florida	(a)	....	....
Georgia	(a)	....	2, 000
Idaho	2, 490	....	3, 000
Illinois	17, 896	10, 000	7, 500
Indiana	43, 983	90, 000	80, 000
Iowa	80, 251	50, 000	25, 000
Kansas	149, 289	80, 000	70, 000
Kentucky	117, 940	80, 000	65, 000
Maryland	10, 605	10, 000	5, 000
Massachusetts	649, 097	400, 000	400, 000
Michigan	246, 570	275, 000	500, 000
Minnesota	131, 979	290, 000	175, 000
Missouri	155, 557	100, 000	125, 000
Montana	31, 648	35, 000	35, 000
Nevada	(a)	....	....
New Hampshire	3, 750	....	....
New Jersey	597, 309	400, 000	350, 000
New Mexico	186, 804	50, 000	20, 000
New York	702, 419	500, 000	450, 000
North Carolina	12, 000	15, 000	....
Ohio	3, 046, 656	3, 200, 000	3, 300, 000
Oregon	8, 424	....	35, 000
Pennsylvania	1, 609, 159	750, 000	650, 000
Rhode Island	(a)	....	....
South Dakota	93, 570	25, 000	20, 000
Tennessee	2, 722	....	....
Texas	14, 651	6, 000	48, 000
Utah	48, 306	36, 000	40, 000
Vermont	(a)	....	....
Virginia	11, 500	40, 000	....
Washington	75, 936	75, 000	75, 000
West Virginia	140, 687	90, 000	85, 000
Wisconsin	183, 958	417, 000	400, 000
Wyoming	16, 760	25, 000	15, 000
Total	10, 816, 057	8, 700, 000	8, 315, 500

a Sandstone valued at $26,199 was produced by Rhode Island, Nevada, Vermont, Florida, and Georgia together, and this sum is included in the total.

Value of sandstone, by States, from 1890 to 1896—Continued.

State.	1893.	1894.	1895.	1896.
Alabama	$5,400	$18,100	$31,930	$48,000
Arizona	46,400	....	20,000	10,000
Arkansas	3,292	2,365	13,228	1,400
California	26,314	10,087	11,933	7,267
Colorado	126,077	69,105	63,237	58,989
Connecticut	570,346	322,934	397,853	426,029
Florida	....	....	....	....
Georgia	....	11,300	....	1,250
Idaho	2,005	10,529	6,900	16,060
Illinois	16,859	10,732	6,558	15,061
Indiana	20,000	22,120	60,000	32,847
Iowa	18,347	11,639	5,575	12,351
Kansas	24,761	30,265	93,394	18,804
Kentucky	18,000	27,868	25,000	....
Maryland	360	3,450	16,836	10,713
Massachusetts	223,348	160,231	339,487	304,361
Michigan	75,547	34,066	159,075	111,321
Minnesota	80,296	8,415	74,700	202,900
Missouri	75,701	131,687	100,000	51,144
Montana	42,300	16,500	31,069	3,250
Nevada	....	....	....	....
New Hampshire	....	....	....	....
New Jersey	267,514	217,941	111,823	126,534
New Mexico	4,922	300	2,700	....
New York	415,318	450,992	415,644	223,175
North Carolina	....	....	3,500	13,250
Ohio	2,201,932	1,777,034	1,449,659	1,679,265
Oregon	....	....	....	....
Pennsylvania	622,552	349,787	500,000	446,926
Rhode Island	....	....	....	....
South Dakota	36,165	9,000	26,100	37,077
Tennessee	....	....	....	4,100
Texas	77,675	62,350	97,336	36,000
Utah	136,462	15,428	5,000	7,860
Vermont	....	....	....	....
Virginia	3,830	2,258	....	....
Washington	15,000	6,611	14,777	11,090
West Virginia	46,135	63,865	40,000	24,693
Wisconsin	92,193	94,888	78,000	65,017
Wyoming	100	4,000	10,000	16,465
Total	5,295,151	3,955,847	4,211,314	4,023,199

THE SANDSTONE INDUSTRY IN THE VARIOUS STATES.

Arizona.—Arizona seems to have gotten steadily under way as a sandstone-producing State, and in spite of hard times yielded $10,000 worth of product in 1896. That a comparatively new enterprise should have done anything at all last year speaks well for its standing.

The following information was submitted by the Arizona Company, operating quarries at Flagstaff. The crushing-strength tests were made at the navy-yard, Washington, D. C., in June, 1889:

Crushing tests of sandstone from Flagstaff, Arizona.

No.	Dimensions.	Cracked at—	Crushed at—
	Inches.	*Pounds.*	*Pounds.*
1	2.01 x 2.03 x 1.98	23,600	23,490
2	2.00 x 2.02 x 2.00	24,000	25,110
3	2.00 x 2.01 x 2.01	25,000	25,490
4	2.00 x 2.00 x 2.00	22,100	22,440

The following analytical results were obtained by Prof. F. W. Clarke, of the United States Geological Survey.

Analysis of sandstone from Flagstaff, Arizona.

	Per cent.
Silica insoluble in acid	79.15
Soluble silica	.04
Alumina (Al_2O_3)	1.30
Ferric oxide (Fe_2O_3)	2.45
Ferrous oxide (FeO)	None.
Lime (CaO)	7.76
Magnesia (MgO)	.23
Carbon dioxide (CO_2)	5.77
Water (H_2O) at 110° C	.32
Water at red heat	2.94
Total	99.96

Specific gravity		2.346
Weight per cubic foot (dry)	pounds	142
Percentage of water absorbed (saturated)		3.76

The following information is the result of investigations by Prof. E. W. Hilgard, of the Agricultural Experiment Station, University of California.

Composition of sandstone from Flagstaff, Arizona.

	Per cent
Sand and siliceous cement	71.33
Carbonate of lime	14.63
Crystallized insoluble silicates embedded in cement	8.23
Soluble silicates (zeolites) forming part of cement	2.67
Ferric oxide	2.07
Moisture	.06
Chemically combined water and loss	.07
Total	99.06

The stone in its natural condition, on prolonged immersion, absorbs about 4 per cent of its weight in water. Its base is formed by about 71 per cent of sand consisting of angular grains of quartz and feldspar, cemented by a cement chiefly siliceous, with a small proportion of zeolitic material, which has been subsequently to its formation impregnated with a solution of lime carbonate, the latter now forming nearly 15 per cent of the mass. Its red color is due to a small amount of red oxide of iron (red ocher), unchangeable in color, which has apparently no part in the cement of the stone. On treatment with dilute muriatic acid, the carbonate of lime is dissolved without materially affecting the firmness of the stone, even after remaining in the acid for four days.

On treatment with strong hot muriatic acid for six hours (at steam heat) the stone, though whitened by the solution of the iron oxide and by the partial decomposition of the zeolitic portion of the cement, still retains its form and coherence, although sensibly softened. This stone is a very durable one. From its slight absorption of water it is not liable to be injured even by freezing, and it is certain to endure well in the climate of California, even where, as in cities, the rain water and air may be somewhat acid. The fact that the stone is not dependent upon the carbonate of lime for its coherence, as shown by the above experiments, removes it from the class of calcareous sandstones, properly so called, which almost necessarily disintegrate when subjected to city smoke. Its color is practicably unalterable and is very attractive, as shown in numerous large buildings in Denver and elsewhere.

California.—As is the case with the other varieties of stone in California, but little was done in 1896. Better conditions of trade must exist before any material improvement in the industry can be expected. The output was small and less than in 1895. Sandstone from quarries at Niles, Alameda County, showed as the average result of tests on ten samples a crushing strength of 10,000 pounds to the square inch. The tests were made at the University of California.

Colorado.—Production fell off from $63,237 to $58,989 in 1896. In prosperous times Colorado is capable of producing and selling much larger quantities than have been quarried during the past few years. Lack of demand is all that prevents the opening of a number of easily worked quarries.

Connecticut.—The sandstone industry of Connecticut is a very important one. Production increased from a valuation of $397,853 in 1895 to $426,029 in 1896. The most productive quarries are those near Cromwell and Middletown, which are well known and have been productive for many years.

The following results of crushing tests made by Maj. J. W. Reilly, of the Watertown Arsenal, were submitted by the Brainerd, Shaler, and Hall Quarry Company of Portland. They show the resistance to gradually applied pressure, surface faced with plaster of Paris to secure even bearings in the testing machine, pyramidal fractures.

Physical tests of Connecticut sandstone.

Test No.	Marks.	Dimensions.			Sectional area.	First crack.	Ultimate strength.		Classification.
		Height.	Compressed surface.				Total.	Pounds per square inch.	
		Inches.	*Inches.*	*Inches.*	*Sq. in.*	*Pounds.*	*Pounds.*		
7330	No. 1 A	2.50	2.50	2.45	6.13	84,800	85,700	13,980	1st quality.
7331	No. 1 B	2.50	2.48	2.47	6.13	81,700	81,700	13,330	Do.
7332	No. 1 C	2.98	3.00	2.95	8.85	123,200	123,200	13,920	2d quality.
7333	No. 1 D	2.95	2.98	2.97	8.85	122,000	132,950	15,020	3d quality.
7334	No. 2 A	2.51	2.55	2.53	6.45	63,850	63,850	9,900	Bridge.
7335	No. 2 B	2.48	2.48	2.52	6.25	58,340	58,340	9,330	Do.

The following tests by Mr. Ira H. Woolson, M. E., of the Engineering Department, Columbia College, School of Mines, were made in the latter part of December, 1896. These results were submitted by the Middlesex Quarry Company, of Portland.

Physical tests of Portland sandstone.

	Mark.			
	1.	2.	3.	4.
Test number	1653	1654	1655	1656
How tested	Bed.	Bed.	Bed.	Bed.
Grain	Fine.	Fine.	Fine.	Fine.
Shape of test piece	Cube.	Cube.	Cube.	Cube.
Length or height in inches	3.017	2.982	3.000	3.006
Diameter or breadth in inches	3.017	3.005	3.010	2.983
Thickness in inches	3.019	2.989	3.019	3.015
Area in square inches	9.108	8.981	9.087	8.993
Stress in pounds compression:				
First crack	100,000	94,000	75,200	111,000
Maximum	105,700	94,000	87,500	112,400
Per square inch maximum	11,605	10,466	9,629	12,498

Average resistance, 11,049 pounds per square inch.

Transverse tests.

No. of test.	Distance between end supports.	Dimensions.		Ultimate strength.	
		Breadth.	Depth.	Total.	Modulus of rupture R.
	Inches.	*Inches.*	*Inches.*	*Pounds.*	*Pounds.*
1669	19	3.99	6.00	11,500	2,282
1670	19	4.00	6.00	9,400	1,860
1671	19	4.00	5.99	10,200	2,025
1672	19	3.98	6.00	10,900	2,168

Average modulus of rupture R. 2,084 pounds.

The following compression and transverse tests were made by Prof. Ira H. Woolson, of New York City:

Additional tests of sandstone from Portland, Connecticut.

	Mark.			
	1.	2.	3.	4.
Test number	1657	1658	1659	1660
How tested	Bed.	Bed.	Bed.	Bed.
Grain	Moderately coarse.	Fine.	Fine.	Very coarse.
Shape of test piece	Cube.	Cube.	Cube.	Cube.
Original dimensions:				
Length or height in inches.	3.017	2.977	3.007	3.011
Diameter or breadth in inches	3.004	3.000	3.022	3.014
Thickness in inches	3.007	3.011	3.003	3.005
Area in square inches	9.033	9.033	9.075	9.057
First crack	107,600	98,200	112,400	102,300
Stress in pounds compression:				
Maximum on specimen	110,400	98,200	112,400	102,400
Maximum per square inch.	12,221	10,871	12,385	11,306

Transverse tests.

[All tested on edge of grain, or right angled to bed.]

Number of tests.	Distance between end supports.	Dimensions.		Ultimate strength.	
		Breadth.	Depth.	Total.	Modulus of rupture R.
	Inches.	*Inches.*	*Inches.*	*Pounds.*	*Pounds.*
1665	19	4.02	6.01	9,500	1,864
1666	19	3.99	5.98	9,300	1,857
1667	19	4.01	6.00	10,500	2,073
1668	19	4.00	6.01	9,800	1,933

The following compression and transverse tests of brownstone for the New England Brown Stone Quarries were made by Prof. I. H. Woolson, of New York City:

Physical tests of New England brownstone, Portland, Connecticut.

	Mark.			
	1.	2.	3.	4.
Test number	1649	1650	1651	1652
How tested	Bed.	Bed.	Bed.	Bed.
Grain	Fine.	Fine.	Fine.	Fine.
Shape of test piece	Cube.	Cube.	Cube.	Cube.
Original dimensions:				
Length or height in inches	3.019	3.037	3.021	3.026
Diameter or breadth in inches.	3.020	3.010	3.043	3.035
Thickness in inches	2.995	3.035	3.034	3.048
Area in square inches	9.044	9.135	9.232	9.250
First crack	111,800	110,000	117,100	92,400
Stress in pounds—compression:				
Maximum on specimen	117,100	110,000	117,100	98,000
Maximum per square inch	12,947	12,041	12,947	10,594

Transverse tests.

[All tested on edge, at right angles to bed.]

No. of test.	Distance between end supports.	Dimensions.		Ultimate strength.	
		Breadth.	Depth.	Total.	Modulus of rupture R.
	Inches.	*Inches.*	*Inches.*	*Pounds.*	*Pounds.*
1673	19	4.01	5.99	9,900	1,961
1674	19	4.11	6.04	10,400	1,977

Tabulation and summary of tests made upon Connecticut brownstone.[1]

TESTS FOR RESISTANCE; 3-INCH CUBES.

Stone from—	Number.	Crushed at—	Resistance per square inch.
		Pounds.	*Pounds.*
Brainerd, Shaler & Hall Quarry Co	1	110,400	12,221
	2	98,200	10,871
	3	112,400	12,385
	4	102,400	11,306
Middlesex Quarry Co	1	105,700	11,605
	2	94,000	10,466
	3	87,500	9,629
	4	112,400	12,498
New England Brown Stone Co	1	117,100	12,947
	2	110,000	12,041
	3	117,100	12,947
	4	98,000	10,594

[1] By Prof. Ira H. Woolson, E. M., School of Mines, Columbia University, New York.

Total number of specimens, 12.
Average resistance of the 12 specimens, 11,625.

TRANSVERSE TESTS; SECTIONS 4 BY 6 BY 20 INCHES.

From—	Number.	Ultimate strength.	Modulus of rupture, R.
		Pounds.	*Pounds.*
Brainerd, Shaler & Hall Quarry Co	1	9,500	1,864
	2	9,300	1,857
	3	10,500	2,073
	4	9,800	1,933
Middlesex Quarry Co	1	11,500	2,282
	2	9,400	1,860
	3	10,200	2,025
	4	10,900	2,168
New England Brown Stone Co	1	9,900	1,961
	2	10,400	1,977

Total specimens, 10.
Distance between supports, 19 inches.
Average modulus of rupture R., 2,000 pounds.

Idaho.—Sandstone is produced near Boise to a limited extent. Production reached a valuation of $16,060 in 1896, an increase over 1895.

Illinois.—The value of the output in 1896 was $15,061, about double the output of 1895. The industry in Illinois has never been large.

Indiana.—The value of the product in 1896 was $32,847; in 1895 it was $60,000. In 1891 the corresponding figure was $90,000. See report for 1895 for detailed information on Indiana sandstone. In addition the following results of investigation by Prof. W. S. Blatchley, State geologist of Indiana, are submitted. The report was made in November, 1895.

Crushing tests of sandstone from Riverside, Indiana.

	Per square inch.
	Pounds.
1. Gray sample	6,000
2. Blue sample	6,090

Chemical analysis of sandstone from Riverside, Indiana.

	Per cent.
Insoluble residue (silica SiO_2)	93.16
Alumina (Al_2O_3)	1.60
Iron oxide (Fe_2O_3)	2.69
Lime (CaO)	.13
Total	97.58

The analysis shows but little material injurious to the durability of the stone. The following are the results of the absorption and fire tests made at the Rose Polytechnic Institute, of Terre Haute, Indiana, on specimens of stone from same quarry:

Each specimen was soaked in water 25 hours, having previously been carefully weighed. It was then removed, wiped dry, and weighed again. The results were as follows:

Bluestone, specimen C: Water absorbed in per cent of dry weight, 6.8 per cent. Specimen C_2: Water absorbed in per cent of dry weight, 4.8 per cent. Graystone, specimen D: Water absorbed in per cent of dry weight, 6.1 per cent. Specimen D_2: Water absorbed in per cent of dry weight, 5.8 per cent.

In fire tests of blue Riverside sandstone the cold specimen and cold lead were placed in crucible and heated until lead would melt on surface of stone; the specimen was then cooled in air. It cracked through center, though pieces did not separate. Specimen No. 2, gray Riverside sandstone, gave the same results as above in every respect.

Iowa.—A small output was obtained in 1896. The industry is not yet important in this State.

Kansas.—A small quantity of sandstone is annually produced.

Maryland.—A small amount of sandstone is annually produced in Montgomery County.

Massachusetts.—The sandstone output of 1895 amounted to a valuation of $339,487; the figure for 1896 was $304,361. Most of the product comes from quarries at Worcester and East Long Meadow.

Michigan.—The value of the output declined from $159,075 in 1895 to $111,321 in 1896. In prosperous times the output would undoubtedly be much greater, as the sandstone is well known and popular; some of it is quarried for abrasive purposes.

Minnesota.—The production of sandstone in Minnesota has shown a large increase during the past year, namely, from a valuation of $74,700 in 1895 to $202,900 in 1896. This is due to largely increased operations of a few firms in Pine County.

The following is an analysis of the Kettle River sandstone by Prof. N. H. Winchell:

Analysis of Kettle River sandstone.

	Per cent.
Water (H_2O)	0.00
Silica (SiO_2)	98.69
Alumina (Al_2O_3)	1.06
Ferric oxide (Fe_2O_3)	Slight tr.
Lime (CaO)	.42
Magnesia (MgO)	.01
Soda (Na_2O)	.17
Total	100.35

The following crushing tests of the same stone were made at the Watertown Arsenal:

Crushing strength of Kettle River sandstone.

	Total pounds.	Per square inch.
		Pounds.
4-inch cube	204,100	12,295
4-inch cube	109,900	12,799

Missouri.—About half as much quarrying was done in 1896 as in 1895. The value of the output in 1896 was $51,144.

Montana.—Very little was done in 1896.

New Jersey.—An increase of output characterized the industry in 1896. The value in 1895 was $111,823; in 1896, $126,534. Sandstone from Montclair, New Jersey, is reported to have shown a crushing strength of 23,000 pounds to the square inch.

New York.—The sandstone output was valued at $415,644 in 1895, but the depressed conditions of trade permitted of only $223,175 in 1896. The sandstones of New York enjoy a long-established reputation for their general desirability as building stones.

North Carolina.—Production increased from $3,500 in 1895 to $13,250 in 1896. The following is a statement of the results of an analysis of brownstone from the Aldrich stone quarries at Sanford, North Carolina. The analysis was made by Dr. F. A. Genth, jr.:

Analysis of brown sandstone from Sanford, North Carolina.

	Per cent.
Moisture	0.79
Silica (SiO_2)	81.59
Ferric oxide (Fe_2O_3)	4.38
Alumina (Al_2O_3)	10.81
Magnesia (MgO)	.33
Lime (CaO)	1.02
Potash and soda (K_2O and Na_2O)	1.08
Total	100.00

The greater portion of this rock consists of a hard-grained quartz sand, mixed with silicates not easily acted upon by atmospheric influences.

Sandstone from Moore County has also been analyzed. The following table gives results:

Analysis of sandstone from Moore County, North Carolina.

	Per cent.
Silica (SiO_2)	84.97
Alumina (Al_2O_3)	10.31
Ferric oxide (Fe_2O_3)	1.41
Manganese (MnO_2)	.07
Lime (CaO)	1.05
Magnesia (MgO)	.79
Potash (K_2O)	.24
Combined water	1.15
Total	99.99

Ohio.—Ohio stands far in the lead of all other States in the production of sandstone. Most of the product comes from quarries in the northern part of the State. The value of the output in 1895 was $1,449,659; in 1896 the value was $1,679,265. It is evident that a very substantial advance was made. Strikes characterized the industry at certain localities during the year. The product is used for building, curbing, flagging, grindstones, and whetstones.

Pennsylvania.—The output of sandstone in 1895 was valued at $500,000; in 1896 the figure was $446,926; a decrease. The following paper by Prof. T. C. Hopkins, of State College, is a valuable contribution to the literature on the subject of sandstones, representing as it does careful and laborious research in connection with this important item of the mineral resources of Pennsylvania.

BROWNSTONES OF PENNSYLVANIA.

By T. C. Hopkins.

Brownstones are among the oldest, best known, and handsomest building stones used in this country. The brownstone fronts of New York and other Eastern cities are found in the most fashionable parts of the cities and in great numbers. It is true that some years ago the use of brownstone was simply fashion, so much so that all the quarries, running to their full capacity, could not supply the demand. As a result there are long blocks of gloomy brownstone houses, with no mingling of colors and little variety of form to relieve the monotony. A reaction has now set in and the fashion is for light stone. As a result we shall in a few years have similar monotonous blocks of light-colored limestone, marble, and sandstone. By the time this second climax is passed a more rational mode of procedure will prevail; architects and builders will begin to use stone that will harmonize with the plan and style of the building and with its location and surroundings. Good building stone of different kinds and different colors will be in demand. The use of brownstone will again increase, as it is a useful and valuable building stone if properly used and not abused.

Much has been written on the paleontology, structural features, and relations of Eastern brownstones and published in the various journals and proceedings of scientific societies. These papers are all classified and enumerated in Bulletin 85 of the United States Geological Survey—The Newark System, by Prof. I. C. Russell—and only those that have any bearing on the economics of the Pennsylvania brownstones are mentioned below. All of these are very brief, very general, and, with one exception, local. There may possibly be a few references to the occurrence of the brownstone in other reports of the Pennsylvania Geological Survey, but none that have any bearing on the economic side of the question. Prof. George P. Merrill's work on building stones and the Tenth Census Report referred to below describe briefly the building stones of all the States.

1. D'INVILLIERS, E. V. Annual Report Geological Survey of Pennsylvania, 1886, Part IV, pp. 1563–1567, Paint, Iron Ore, Limestone, and Serpentine.—Brief description of the brownstone quarries in the vicinity of Hummelstown.

2. FRAZER, PERSIFOR. Report of a geological survey of Chester County, 1880, C 4, Second Pennsylvania Geological Survey, pp. 178–214.—The stratigraphic and paleontologic relations of the Mesozoic red sandstone in Chester County.

3. FRAZER, PERSIFOR, JR. The geology of Lancaster County, Second Geological Survey of Pennsylvania, 1877, CCC.—Mentions the occurrence of the New Red Sandstone in Lancaster County.

4. LYMAN, BENJ. SMITH. Report on the New Red of Bucks and Montgomery counties, by Benj. Smith Lyman, in Summary Final Report Geology of Pennsylvania, Vol. III, part 2, pp. 2589–2638, 1895.—Gives geologic and topographic map and cross sections of the New Red of Bucks and Montgomery counties, with a detailed account of the stratigraphy, paleontology, and general scientific features; brief mention of the economic features.

5. MERRILL, G. P. Stones for building and decoration, Wiley & Son, New York, 1891, pp. 279–281.—Also in Smithsonian Report, part 2, 1886.

6. SHALER, N. S. Description of quarries and quarry regions, Tenth Census, Vol. X, pp. 156–157.—One of the best short descriptions of the brownstones of Pennsylvania.

GENERAL PROPERTIES OF BROWNSTONES.

Definition.—It might at first glance seem superfluous to offer a definition of such a simple term as brownstone, but the very fact that it is used with different meanings in the market is a reason why it is advisable to state the significance of the word as used in this report.

If all the brownstone occurred in one locality and were all of one shade or color the term would be self-explanatory, but stone with a more or less brown tint occurs in a dozen or more States and at several different geologic horizons, some of which may be called brown by one person and red, gray, brown, or something else by another. In some localities the term brownstone signifies the Portland, Connecticut, stone, because that is used in such large quantities and no other is there known. With some persons it signifies any rock from the Mesozoic or New Red formation, whether it be really brown or not. In this report the term is used for any stone that has a brown or red color, irrespective of locality or the geological formation in which it occurs. A light stone which is brown only in places, and which occurs in the New Red formation, is also included, because it is closely associated with brownstone, often in the same quarry, and because it frequently passes in the market as brownstone. Some of the so-called Trenton brownstone is not brown at all. There is also included red or brown stone from the Paleozoic rocks which may not be generally known in the market under the name brownstone, but which is as truly brown in color as many of the original brownstones. Hence the term is here used to designate a sandstone with a brown or red color, rather than a brownstone from any particular locality or formation. The red or brown marbles are not included.

Colors.—Brown is defined as a dark color shading toward red, yellow, or black, and may be produced by a mixture of these colors.[1]

[1] Standard Dictionary.

We can thus see that there may be an almost infinite number of shades of brown, grading insensibly into red, yellow, or black, and that there may be a wide divergence of opinion as to where the division should be made. In the sandstones the change is most frequently toward the red, less commonly toward the yellow. So close is the relation that the same stone is called by some dealers red and by others brown.

From the standpoint of color it is one of the best of building stones, not only from the wide range of shades to select from but from the inherent beauty and richness of many of the shades, and, what is of great importance in architecture, the permanency of the color. There is probably not another color common among building stones that is as permanent and as little liable to tarnish as brown. Where brownstone is used to excess, particularly dark shades, and along narrow streets, it is gloomy and somber. It is at its best advantage when used along with other colored building stones, or at least with the liberal use of lighter brownstones. The darker colored stones, while more somber than the lighter shades, show the dirt and stains of the city atmosphere less and are in this respect better adapted to base courses and trimmings. The inherent beauty and permanency in the color, together with its durability in combination with stones of other colors for architectural effect, will always cause a demand for brownstone by the best architects.

The brownstones of Pennsylvania have as wide a range in color as those of any other State. There is the rich blue-brown and red-brown stone of Hummelstown, the dark-brown at Mohnsville, the light red-brown at Cornwall, the light purplish-brown at Newtown and Yardley, the very light brown to gray at Lumberville, Grenoble, and Fort Washington, the light pink south of Birdsboro, and the light red and dark red at White Haven and Laurel Run.

THE CHEMICAL COMPOSITION OF BROWNSTONES.

The accompanying tables of analyses give the chemical composition of all the well-known brownstones in this country so far as they could be obtained. The first table gives those of Pennsylvania; the second, those from other States. It may be noticed in comparing these that the figures for the Hummelstown stone, the best-known brownstone of Pennsylvania, correspond more nearly with those of the East Long Meadow, Massachusetts, sandstone than any other. The stones of the eastern part of Pennsylvania more nearly resemble the Portland, Connecticut, stones in composition than any others in the State.

The signification of the varying proportions of the different substances is not always perfectly clear, but a number of very useful deductions can be made, as follows: Of all the substances mentioned silica is the most durable, especially if it occurs in the form of quartz. If it is desirable to have the percentage of silica as high as is consistent with the desired hardness and workability of the stone—that is, from the standpoint of durability alone, quartz is the most desirable substance, but if the silica is all in quartz grains and the percentage too high the stone will be friable, not having sufficient cement to hold the grains together. On the other hand, if part of the silica is in the form of cement, binding the grains together, the stone is liable to be too hard to work. Hence, no definite limit can be placed on the amount of silica allowable in a good stone, as that depends on whether a hard stone or an easy-working stone is desired, and also on how much of the silica is in feldspar, mica, or clay. The proportions of alkali, lime, and alumina throw much light on this point. It also depends on the size and shape of the grains. Thus, round grains require more and stronger cement than sharply angular grains to produce a stone of equal strength; irregular angular grains, when closely compact, will make a very strong stone with very little cement. A high percentage of alumina is not desirable; if in the form of feldspar or mica, it is a source of decay; if in the form of clay, it will absorb water and injure the stone by freezing. The last injury is intensified if the clay is segregated in patches or layers. On the other hand, a certain percentage of clay is desirable to make an easy-working stone. If the cement is entirely or largely quartz or calcite, the stone will be too hard to work freely. No arbitrary standard can be given for the maximum percentage of alumina allowable, as that depends on the form in which it occurs, the manner of its distribution, and the character of the grains containing it.

The iron is desirable within reasonable limits, providing it occurs in the peroxide form, as it gives the color to the stone and forms a strong and durable cement. If it occurs in the form of pyrite or carbonate it is liable to be a source of disintegration. It is customary in making the analyses to determine the iron as peroxide without proving it to be such. Hence the small percentage of protoxide given with the Hummelstown stone does not signify that it does not occur in any of the others, but simply that it was not determined in any of the others, and is given to show that it does not occur in sufficient quantities in the Hummelstown stone to be any serious injury to the stone, as might be suggested by its blue color.

The lime is not a desirable element, but it is probably less injurious in the form of feldspar (the form in which much of it occurs in the tables) than in the form of calcite, as in the latter case it hardens the stone, and where it does not form all the cement, hardens it unequally, and in the presence of acids is liable to be a source of weakness. In the first instance the only injury is in the presence of feldspar, which is liable to decay. The alkalies are not desirable, on account of their solubility and the tendency of the substances in which they occur to disintegrate.

The following table shows the chemical composition of the Pennsylvania brownstones:

Analyses of Pennsylvania brownstones.

No.	Location of quarry.	Specific gravity.	Silica (SiO_2).	Alumina (Al_2O_3).	Ferric oxide (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Potash (K_2O).	Soda (Na_2O).	Ferrous oxide (FeO).	Manganese dioxide (MnO_2).	Water (H_2O).	Total.
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	Hummelstown Brown Stone Co.—blue	2.657	90.34	4.35	1.09	0.95	0.17	1.30	0.19	0.74	....	0.61	99.74
2	Hummelstown Brown Stone Co.—brown	2.669	88.96	4.74	2.19	.86	.44	1.31	.24	....	....	.87	99.61
3	Swatara Brown Stone Co.	....	91.52	3.80	2.02	.50	.22	a1.20	....	....	....	.74	100.00
4	Mount Gretna	2.695	91.07	2.68	3.29	.23	.33	1.12	.24	....	....	.73	99.69
5	Westley's Quarry, Mohnsville	2.73	84.96	7.78	3.71	.10	.38	1.11	.43	....	0.18	1.40	100.05
6	Grenoble Station	2.66	79.08	12.42	2.50	....	....	2.02	3.00	....	.09	.55	99.66
7	Mitchell's Quarry, Newtown	2.66	82.34	11.46	1.07	.27	.19	.17	3.76	....	.07	.80	100.13
8	Yardley Quarry, Yardley	2.675	82.72	10.29	1.92	.17	.36	.10	2.92	....	.16	1.20	99.84
9	Hummelstown	....	88.13	5.81	1.77	.20	.53	2.63	.06	.31	....	.49	99.93
10	Laurel Run Red Stone, Laurel Run	2.666	b94.00	Trace.	1.98	1.10	1.00	....	....	....	Trace.	c1.92	100.00
11	Daneker's Quarry, White Haven	....	90.36	2.17	d1.15	2.00	Trace.	....	....	....	....	....	95.68

a Includes alkalies and loss. b Silica and insoluble residue. c Volatile matter—water and carbonic acid. d Given as protoxide, evidently a mistake.

NOTE.—Analyses 1-8, inclusive, made in the chemical laboratory at State College, Pa. No. 9, by E. A. Schneider, Bulletin 90, U. S. Geol. Survey, page 65; No. 10, by A. A. Breneman, New York; No. 11, by Crane Iron Company laboratory.

The following table shows the chemical composition of various brownstones:

Analyses of brownstones.

No.	Locality.	Silica (SiO_2).	Alumina (Al_2O_3).	Iron oxide (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Alkalies.	Water.	Total.	Authority.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
12	Portland, Conn	69.94	13.15	2.48	3.09	Trace.	8.73	[a] 1.01	....	Merrill, Building and Ornamental Stones, page 420.
		70.11	13.49	4.85	2.39	1.44	7.37	....	99.65	
13	Cromwell, Conn	70.84	13.15	2.48	3.09	Trace.	8.73	1.01	99.30	New England Brown Stone Co.
14	East Longmeadow, Mass., Worcester Quarry.	88.89	5.95	1.79	.27	....	.86	[a] 1.83	100.00	Worcester Polytechnic Institute.
15	East Longmeadow, Mass., Maynard Quarry.	79.38	8.75	2.43	2.57	....	4.08	[a] 2.79	100.00	Do.
16	Wilburtha, N. J	93.55	4.00	....	.40	.18	.30	.12	98.55	Geology of N. J., 1868, page 515.
17	.....do	93.60	1.59	3.30	....	....	.35	1.20	100.04	Geology of N. J., 1868, page 516.
18	Milford, N. J	79.25	7.49	3.78	1.86	....	1.12	3.16	[b] 99.51	Do.
19	Center Bridge, N. J	96.20	1.58	[c] 1.37	.15	.36	....	1.15	100.81	Geology of N. J., 1868, page 515.
20	Washington Valley, N. J.	88.45	3.92	3.03	.36	.12	.88	[d] 1.94	98.70	Do.
21	Hancock, Md	76.43	17.78		.84	.92	....	....	98.76	Bulletin 55, U. S. G. S., page 80.
22	.....do	[e] 88.68	....	7.13	1.32	.66	....	2.20	99.99	Do.
23	Sanford, N. C., brown	81.59	10.81	4.38	1.02	.33	1.08	.79	100.00	Garrett and Dix, Philadelphia.
24	Sanford, N. C., red	82.58	8.95	3.95	1.18	.81	.83	1.68	99.98	Do.
25	Mansfield, Ind	[e] 92.16	....	6.29	.05	....	.09	....	98.59	Rose Polytechnic Institute.

a Includes water, CO_2, and loss. No. 14 contains 0.41 per cent manganese dioxide.
b Includes also sulphuric acid 1.39 per cent and carbonic acid 1.46 per cent.
c Iron given as protoxide.
d Includes 0.14 per cent SO_3.
e Insoluble residue includes silica and insoluble silicates. No. 21 includes also 2.79 per cent loss by ignition, and is an analysis of the same as 22, in which all the silica is determined by fusion with soda carbonate; both from the Jaitelle Quarry.

Analyses of brownstones—Continued.

No.	Locality.	Silica (SiO_2).	Alumina (Al_2O_3).	Iron oxide (Fe_2O_3).	Lime (CaO).	Magnesia (MgO).	Alkalies.	Water.	Total.	Authority.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
26	St. Anthony, Ind	*a* 88.41	.63	8.40	.13	....	....	....	97.57	Rose Polytechnic Institute.
27	Bloomfield, Ind	*a* 85.29	.19	11.83	.06	....	....	....	97.37	Do.
28	Greenhill, Ind	*a* 98.73	.28	.36	.03	....	....	....	99.40	Do.
29	Hillsboro, Ind	*a* 91.65	.56	6.60	.12	....	....	....	98.93	Do.
30	L'Anse, Mich	*a* 78.55	14.21	5.54	.42	Trace.	....	....	98.72	
31	Portage Entry, Mich	90.17	4.23	3.16	....	.29	....	1.01	98.86	Maurier and Hoskins, Chicago.
32	......do	82.60	8.32	.28	.55	.18	6.49	.99	99.41	Report Geol. Survey Mich., 1891-92.
33	Marquette, Mich	77.18	9.69	3.20	0.26	1.48	4.85	2.90	*b* 100.00	F. F. Sharpless.
34	Keweenaw Bay, Mich	78.55	14.21	5.54	.42	Trace.	....	1.28	100.00	Stone, Vol. IX, No. 1.
35	Houghton, Wis	91.40	3.53	2.00	.25	....	2.50	.05	99.73	Columbia College School of Mines.
36	Bass Island, Wis	87.02	7.17	3.91	.11	.06	1.65	Trace.	99.92	Geol. of Wis., Vol. III, page 208.
37	Fond du Lac, Wis	78.24	10.88	3.83	.95	1.60	1.73	....	97.23	Geol. of Minn., Vol. I, page 202.
38	Flagstaff, Ariz	79.19	1.30	2.45	7.76	.23	....	3.26	*c* 99.96	Bulletin 78, U. S. G. S., page 124.
39	Kettle River, Minn	98.69	1.06	Trace.	.42	.01	.17	....	100.35	N. H. Winchell.
40	Pipestone, Minn	84.02	12.33	2.12	.31	Trace.	.45	*d* 2.31	101.54	

a Insoluble residue includes silica and insoluble silicates.
b Includes P_2O_5 0.21 per cent and SO_3 0.23 per cent.
c Includes 5.77 per cent CO_2; analyzed by Dr. T. M. Chatard.
d Includes water, CO_2, and loss.

MINERALOGICAL COMPOSITION OF BROWNSTONE.

The mineralogical composition is frequently as valuable an indication of the quality of the stone as the chemical composition, and sometimes more so, especially when combined with a microscopic examination, which shows not only the minerals present, but the relative quantity and the condition in which they occur. The bulk of all sandstones is made up of quartz grains, which generally form from 70 to 95 per cent of the rock. In the quartzites the grains are cemented by quartz deposited in the interstices, thus giving a high percentage of silica. However, a high percentage of silica does not always signify a quartzite, as may be seen on comparing a few analyses in the foregoing tables. Thus, the Mount Gretna and the Hockersville stone each shows more than 91 per cent silica, while the White Haven stone has less than 91 per cent; yet the first two, especially the Mount Gretna stone, are friable sandstones, and the last is a hard quartzite. Likewise, the Wilburtha stone, which has 93 per cent silica, is a soft stone; and the Mansfield (Indiana) stone, with more than 92 per cent silica, is a friable sandstone; and the Lumberville stone, which is a hard quartzite, has less than 80 per cent silica. The advantage of the microscopic examination over the chemical, or rather in combination with the chemical, is that it shows the form in which these elements occur. Thus, the Lumberville stone has the grains of quartz and feldspar firmly bound in a quartz cement which would not be shown by the analysis.

The next most abundant substance after quartz found in the grains of sandstone is feldspar. In some localities orthoclase and microcline, the alkali feldspars, are abundant, while in other places the plagioclase or basic feldspars predominate. As most of the feldspars occur in the sandstone in a more or less decayed condition, where plagioclase abounds calcite is liable to be found in the sandstone, and in many places there is formed on the stone in protected places an efflorescence of sodium or potassium sulphate from the alkali of the feldspar. While this was observed in many places, it was determined by analysis from only one locality, and it proved to be mirabalite, or glauber's salt (sodium sulphate). The resulting products of decaying feldspar are numerous, depending on the conditions under which it decomposes. The most common products are clay, quartz, and muscovite (mica). In none of the brownstones examined was muscovite observed in large flakes where it appeared to be secondary product, but aggregates of clay with much finely granular quartz and minute flakes of what is apparently muscovite are plentiful, sometimes in a rim of feldspar, sometimes with included fragments of partially decayed feldspar—in fact, nearly all stages from fresh feldspar to clay in which the outlines of the feldspar have been lost.

Mica is very scarce in the Pennsylvania brownstones, occurring only in a few widely scattered fragments. It readily decomposes, yet it is an element of weakness, not so much from its disintegration as from the

Crushing strength, specific gravity, and ratio of absorption of brownstones.

No.	Quarry.	Locality.	Crushing strength per square inch.	Number of specimens tested.	Specific gravity.	Weight per cubic foot.	Ratio of absorption.	Authority.
			Pounds.			*Pounds.*		
1	Hummelstown Brown Stone Co.	Hummelstown, Pa.	13,097	3	......	....	....	Riehlé Bros., Philadelphia, Pa.
2	...do	...do	12,810	......	......	....	....	Merrill, Stones for Building and Decorating.
3	Hummelstown Brown Stone Co., No. 3.	...do	14,630	4	......	....	....	Riehlé Bros., Philadelphia, Pa.
4	Hummelstown Brown Stone Co., No. 4.	...do	10,933	4	......	....	....	Do.
5	Hummelstown Brown Stone Co., No. 3.	...do	14,000	3	2.66	146.0	1-27	Rose Polytechnic Institute.
6	...do	...do	14,753	3	......	....	1-37	Watertown Arsenal, Mass.
7	George Brook's quarry	Birdsboro, Pa	11,448	3	......	....	....	Do.
8	Lumberville Granite Co.	Lumberville, Pa.	19,895	4	......	....	1-93	Fairbanks's Laboratory, N. Y.
9	...do	...do	24,625	2	2.60	162.5	1-88	Booth, Garrett & Blair, Philadelphia, Pa.
10	...do	...do	22,025	8	......	....	....	Garrison & Olsen, Philadelphia, Pa.
11	Oliver's quarries	Laurel Run, Pa.	22,250	......	2.66	166.1	....	School of Mines, Columbia College.
12	...do	...do	17,600	12	2.66	166.1	1-900	Cornell University.
13	John Dancker's quarry	White Haven, Pa.	29,252	3	......	....	....	Watertown Arsenal.
14	...do	...do	32,397	7	......	....	....	Do.
15	Portland quarries	Portland, Conn.	12,580	6	2.35	146.9	1-40	Do.
16	...do	Middletown, Conn.	6,250	2	2.63 / 2.36	148.5	1-40	General Gillmore, Chief of Eng., Rep. 1875.
17	New England Brown Stone Co.	Cromwell, Conn	16,894	2	2.68 / 2.50	156.0	1-40	Watertown Arsenal.

coarse, but a uniform coarse-grained stone is better than one having a mixture of coarse and fine grain. As a rule, the coarse-grained rocks are more porous and absorb water more freely, and hence are more liable to injury from the frost. On the other hand, they are less liable to be laminated or "reedy," less liable to have clay seams, will generally work more freely in all directions, and are less liable to be cut up by numerous seams, both vertical and horizontal, than the fine grained ones. The fine-grained stones are generally stronger but less elastic, not so apt to disintegrate, but more apt to crack and shell. They are equally well adapted to rock-faced, tool-dressed, or fine carved work.

The microscope reveals several features in regard to the texture and composition of the rocks that are not brought out in any other way. It reveals both the mineral constituents and their condition of preservation, as well as the proportions, kind, and character of the cement—facts which are given under the different varieties.

PHYSICAL TESTS.

The accompanying table shows specific gravity, absorption, and crushing tests made on brownstones from a number of productive quarries in the United States. In comparing the results made at different places considerable allowance must be made for the fact that different methods produce different results. Thus there are several different methods of obtaining the specific gravity, each of which has its merits, though obtaining different results. The Hummelstown stone appeared from the results to be much heavier than the other brownstones of similar appearance. When, in order to verify the comparison, tests were made in the same manner on other stones, it was discovered that the difference was in the method of taking the specific gravity. A carefully trimmed 6-inch cube of the purple brownstone was found to weigh 18¼ pounds, equal to 146 pounds per cubic foot, the weight from the specific gravity showing 166 pounds, a difference of 20 pounds to the cubic foot. A cube of brownstone gave 150 pounds to the foot, which is the weight used by the company.

Crushing tests made on stone of the same kind, from the same block, all prepared by the same stone-cutter, tested on machines of the same make, but by different operators in different places, show a variation in one set of four samples each of more than 2,000 pounds per square inch, and on another set of more than 4,000 pounds per square inch, or more than one-third of the total strength.

Crushing strength, specific gravity, and ratio of absorption of brownstones.

No.	Quarry.	Locality.	Crushing strength per square inch.	Number of specimens tested.	Specific gravity.	Weight per cubic foot.	Ratio of absorption.	Authority.
			Pounds.			*Pounds.*		
1	Hummelstown Brown Stone Co.	Hummelstown, Pa.....	13,097	3	......	....	....	Riehlé Bros., Philadelphia, Pa.
2	.....do	.....do	12,810	......	......	....	....	Merrill, Stones for Building and Decorating.
3	Hummelstown Brown Stone Co., No. 3.	.....do	14,630	4	......	....	....	Riehlé Bros., Philadelphia, Pa.
4	Hummelstown Brown Stone Co., No. 4.	.....do	10,933	4	......	....	....	Do.
5	Hummelstown Brown Stone Co., No. 3.	.....do	14,000	3	2.66	146.0	1-27	Rose Polytechnic Institute.
6	.....do	.....do	14,753	3	......	....	1-37	Watertown Arsenal, Mass.
7	George Brook's quarry..	Birdsboro, Pa	11,448	3	......	....	....	Do.
8	Lumberville Granite Co.	Lumberville, Pa.......	19,895	4	......	....	1-93	Fairbanks's Laboratory, N. Y.
9	.....do	.....do	24,625	2	2.60	162.5	1-88	Booth, Garrett & Blair, Philadelphia, Pa.
10	.....do	.....do	22,025	8	......	....	....	Garrison & Olsen, Philadelphia, Pa.
11	Oliver's quarries........	Laurel Run, Pa........	22,250	......	2.66	166.1	....	School of Mines, Columbia College.
12	.....do	.....do	17,600	12	2.66	166.1	1-900	Cornell University.
13	John Dancker's quarry..	White Haven, Pa......	29,252	3	......	....	....	Watertown Arsenal.
14	.....do	.....do	32,397	7	......	....	....	Do.
15	Portland quarries	Portland, Conn........	12,580	6	2.35	146.9	1-40	Do.
16	.....do	Middletown, Conn.....	6,250	2	$\begin{cases}2.63\\2.36\end{cases}$	148.5	1-40	General Gillmore, Chief of Eng., Rep. 1875.
17	New England Brown Stone Co.	Cromwell, Conn	16,894	2	$\begin{cases}2.68\\2.50\end{cases}$	156.0	1-40	Watertown Arsenal.

Crushing strength, specific gravity, and ratio of absorption of brownstones—Continued.

No.	Quarry.	Locality.	Crushing strength per square inch.	Number of specimens tested.	Specific gravity.	Weight per cubic foot.	Ratio of absorption.	Authority.
			Pounds.			*Pounds.*		
18	James & Marra (red)	E. Longmeadow, Mass.	12, 210		2.49	154.5	1–23	Watertown Arsenal, July, 1893.
19	James & Marra (brown)	do	12, 330		2.48	154.5		Do.
20	Worcester quarry (brown).	do	10, 936	2	2.49	155.3	1–19	Watertown Arsenal, Dec., 1883, 6-inch cube.
21	Maynard quarry (red)	do	10, 274	1	2.49	155.3	1–20	Watertown Arsenal, Mar., 1889, 6-inch cube.
22		Medina, N. Y.	16, 031	2	2.40	150.0	1–53	General Gillmore, 1875.
23		Little Falls, N. J.	9, 500	2	2.25	140.6	1–34	Do.
24		Potsdam, N. Y.	42, 800	1	2.60	162.3	1–48	School of Mines, Columbia College.
25	J. B. Lynne & Sons	St. Anthony, Ind.	3, 000				1–13	Rose Polytechnic Inst., Terre Haute, Ind.
26		Marquette, Mich.	10, 780				1–50	Stone, June, 1894.
27		do	5, 992	3	2.29	142.8	1–32	General Gillmore.
28		do	6, 150	6	2.16	135.3	1–20	Do.
29		do	3, 800					Geol. Surv. Michigan, 1891 and 1892.
30		Portage Entry, Mich	7, 300		2.54	158.2	1–11	Stone, June, 1894.
31		do	6, 350					Geol. Surv. Michigan, 1891 and 1892.
32		L'Anse, Mich	10, 645					
33		Keweenaw Bay, Mich.	10, 645					Stone, June, 1894.
34		Bass Island, Wis.	4, 662	3	2.04	127.5	1–15	General Gillmore.
35		Fond du Lac, Wis.	6, 237	2	2.22	138.8	1–22	Do.
36		Houghton, Wis	7, 316	2				School of Mines, Columbia College.
37		Wilson Island	7, 548	1		150.0		
38		Fond du Lac, Minn	8, 750		2.25	141.3		The Geol. of Minn., Vol. I, page 200.
39	Minnesota Sandstone Co	Kettle River, Minn	12, 547	2				Watertown Arsenal.

OCCURRENCE OF PENNSYLVANIA BROWNSTONES.

The brownstones, so far as commercially developed, are confined largely to the eastern and southeastern part of the State. The New Red area in which most of the quarries are located extends from the Delaware River north of Trenton in an irregular, rather broad belt west-southwest through Bucks, Montgomery, Berks, Chester, Lebanon, Lancaster, Dauphin, York, and Adams counties. The most productive quarries are those near Hummelstown. Other less productive quarries are at Mount Gretna, Schaefferstown, Mohnsville, Birdsboro, Phœnixville, Valley Forge, Port Kennedy, Fort Washington, Norristown, Grenoble Station, Neshaminy, Newtown, Yardley, and Lumberville. Quarries of a considerable size near Middletown and Goldsboro were once productive, but are now abandoned.

The Mauch Chunk formation, of Lower Carboniferous age, from which the red-brown quartzose sandstone is obtained, surrounds the anthracite coal basin in the eastern part of the State, and, according to the State geological map, underlies the Coal Measures of the west and west-central portion of the State. So far as is known to the writer the only places where the Mauch Chunk red stone has been quarried are the southern part of the north anthracite field and the east end of the middle field at Mocanaqua, Laurel Run, and White Haven. A quarry reported near Rockwood, Somerset County, may be in this formation. There is brownstone in the Catskill, Clinton, and Medina groups in Pennsylvania, but so far as known no quarries have been opened in any of them. Time did not permit a personal examination of these areas to see whether good stone occurred in commercial quantities or not. The fact that there are many productive quarries in the Medina formation in western New York, and the promising appearance of the few outcrops observed in this State, would suggest the possibilities of good brownstone from this formation.

METHODS OF QUARRYING AND HANDLING THE PENNSYLVANIA BROWNSTONES.

In all of the small brownstone quarries the work is mostly done by hand, with the liberal (entirely too liberal for the good of the stone) use of powder. Holes are drilled by hand, either by the churn-drill or the jumper, and heavily charged with powder and fired, loosening sometimes a large quantity of stone. If the blocks thus loosened are too large to be broken by repeated blows with a heavy hammer another charge is put in and the demolition completed. As may be well imagined, but little good dimension stone is quarried in this manner; yet much stone that would be good dimension stone if properly quarried is taken out in this way. Where good dimension stone is required, it is taken out either by splitting from the ledge with wedges (plugs and feathers), or by the Knox blasting system or some similar system. Channeling machines are not used in any of the brownstone quarries of this State, nor is the stone in any of them in such a shape as to require or justify their use. There are numerous seams in all of the quarries, either bedding or joint seams, and by utilizing these seams the stone can be extracted more cheaply by wedging and blasting than by channeling. In the Hummelstown region the strata are too highly inclined to be channeled to advantage. In the larger quarries, like those at Hummelstown, the Knox system of blasting is used, and this, if properly managed, reduces the injury to the stone almost to a minimum. Where the rock occurs in regular layers, after once getting a straight face successive blocks are broken off by putting a row of holes parallel with the face and firing with a battery. The channeling machine may here be used to advantage in cutting out the ends of the quarry, or if on a long face by making cross cuts, if the position of the stone is such that it can be used.

In all small quarries the stone is loaded on the car, boat, or wagon either by hand or with the use of a man-power or horsepower derrick. The larger quarries have steam hoists. Nearly all the quarries in operation are near the railway or canal. The shipping facilities of each is mentioned in the description of the quarry.

USES AND ADAPTABILITY.

Brownstones are used for almost all classes of work for which any other rock is used. It is preeminently a building stone, probably one of the most valuable in the market, and is adapted to as many different classes of structural uses as any other. In Pennsylvania, besides its use as a building stone, it has been used as sand for plastering, masonry, for furnace hearths, lining blast furnaces, monuments and paving blocks, curbing, flagging, stepping stones, macadam, and concrete. But by far the larger part quarried goes into structures of some kind; the better qualities into superstructure, as walls or trimmings, and the inferior grade into foundations, bridge piers and abutments, culverts, retaining walls, etc. The different varieties are all adapted to these different uses if selected with care. Thus, where the stone is to be carved or smooth dressed, a fine-grained stone of homogeneous color and not too hard should be selected; for rock-faced work and heavy masonry the coarse grained can be used; but all kinds are suitable that are sufficiently strong and durable. In bridge piers and foundations mixed stone—that is, stone variegated in color or texture—may be used. In nearly all quarries there is considerable stone that may be as strong and durable as any but is lacking in beauty or homogeneity, and can not be used as first-class stone in superstructures, but which can be used to advantage in bridge work, where strength and not beauty is required.

Soft stones, like those from Newtown and Yardley, are admirably adapted for building in face work or for heavy trimmings, but will not stand the wear in pavements and streets, or heavy cross strain in lintels and sills, unless protected in some way. Stones like those from White

Haven, Wilkesbarre, and Lumberville are sufficiently hard not only for foot wear in pavements, but for street wear, as Belgian blocks or crushed stone. On the other hand, they are not adapted to buildings where much cutting or carving is to be done, on account of their hardness.

To obtain the best architectural effects care must be taken in selecting the colors. This is largely in the hands of the architects and the contractors, but when they persist in putting up entire blocks of dark brownstones along narrow streets it is time that owners and residents should protest. Some shades of brownstone are pretty in themselves; others have their natural beauty intensified and brought out by judicious mingling with other colors and shades. The lighter colored brownstones could be used in larger quantities, either in the same building or the same town, with more pleasing results than the dark colored, but the two together will produce a better effect than either alone. The darker stones are better adapted to business blocks on the principal thoroughfares, as they do not soil or show stain so readily. The lighter colored ones are adapted to residences in the suburbs or country towns. The very hard quartzite varieties should not be used in excess in face work, as the hard, stony glare produced by them is repellent. On a large face this could be relieved in part by an intermingling of sawed or tool-dressed faces among the rock-faced ones.

BROWNSTONE QUARRIES IN THE NEW RED AREA OF PENNSYLVANIA.

Goldsboro.—Brownstone occurs over an extended area in Adams and York counties, but only one quarry of any extent has been opened. That is 2½ miles west of Goldsboro, York County, the nearest railway station. It was opened in 1851 and was operated most of the time until 1869, from which date to 1880 it was in continuous operation. It has been idle since 1880. The stone is a mediumly fine-grained, rather dark colored brown, occurring in a bed 12 to 15 feet thick, overlain by red-brown shale. The product was used for building purposes in many of the towns of south central Pennsylvania, some being shipped as far south as Baltimore and Washington.

Hummelstown and vicinity.—Nine different companies have operated quarries in the vicinity of Hummelstown, but there is only one in active operation at the present time—the Hummelstown Brownstone Company. Some of the companies have been absorbed by this company, some of the quarries abandoned, and some possibly only temporarily idle. The quarries of the Hummelstown Brownstone Company, situated about 3 miles south of Hummelstown, were opened about 1800, and have been in more or less active condition since that date. Their greatest period of activity has been since 1866. Since that date it has ranked among the largest, most productive, and best-known brownstone quarries in this country. Dozens of fine buildings all over eastern and central United States attest its beauty and right to rank among the best brownstones in the country. The company is now operating three quarries, employing 100 or more men; in busy seasons, from 500 to 700 men; has a large, well-equipped mill, 30 steam-power derricks, 2 wire cable ways, 2 steam travelers, abundance of steam drills, a large steam shovel, and their own railway and locomotives, connecting with the Philadelphia and Reading road at Brownstone Station, 2 miles distant.

The strata in this locality all dip about 40° to 45° to the north, thus giving the strike or the line of outcrop an east-west direction. The separate layers vary from 20 inches to 20 feet in thickness. While the bedding planes are not abundant, and, where they do occur, are not conspicuous open seams, yet there is throughout the bed an easy cleavage parallel with the bedding, on which the layers can be readily split into any thickness desired. These seams are more abundant near the outcrop, and least so in the bottom of the quarry. The joint seams in in these quarries are not numerous. The total thickness of the stone is not known. Including the conglomerate and the shales there is certainly not less than several hundred, probably several thousand, feet. The greatest thickness of good quality of brownstone at one place is about 50 feet, as shown in the quarries of this company. But while this is immediately underlain and overlain by red shale and conglomerate, good stone is known to occur both above and below the bed quarried. In fact, some good stone has been quarried from strata both above and below that in the productive quarries. Thus the supply of good stone is practically unlimited. The only question is the economic production of it, which question the company has answered successfully so far. The stone varies somewhat in texture. There are fissile red shale, fine-grained sandstone, and both shale and quartz conglomerate; but there is not an intimate intermingling or gradation of these one into the other, which is noticeable in other localities. The series alternate, but rarely mix, though in places there is a mingling of the shale fragments with the sandstone. There are heavy layers of coarse quartz pebble scattered through the sandstone. The first-class stone is an even-grained, fine-grained stone, remarkably uniform, perhaps unsurpassed in this property by any brownstone in the United States. The texture of the Hummelstown stone is very close and it will take a very smooth finish. The absorption of the stone is about the average for brownstone, but it appears to be harder than the average brownstone.

There are two decided shades of stone from the different quarries. The most abundant shade—the one that comes from all but one of the quarries—is a reddish brown, resembling the East Longmeadow (Massachusetts) stone in color. It is among the darkest-colored ones in this State, those farther east being almost all lighter colored, except that at Mohnsville and Frog Hollow. The other shade is a purplish brown, which comes from their No. 3 quarry. It harmonizes well with the redder tint, and buildings with the lower part of the blue stone and the upper part of the red stone present a good appearance.

The chemical composition, crushing strength, absorption, and specific gravity of this stone are given in the tables on the preceding pages, and show it to have all the essential properties of a strong and durable stone and at the same time to be not too difficult to work. Its durability is shown not only by its composition and tests but by exposure. The Berst house at the quarry was constructed in 1800 and shows not the least sign of decay, the stone not even being discolored. The same is true of other old buildings in the vicinity. It is practically free from mica, and nowhere has it been observed to scale and flake off.

Quarries of more or less local value occur along the mountains eastward from Hummelstown as far as Reading, but no large quarries that do any shipping. In the vicinity of Cornwall and Schaefferstown the stone, which has had considerable local usage, has a light attractive color, but is coarse, most of it containing pebbles.

There are three quarries at Mohnsville, south of Reading, of dark-colored brownstone associated with much conglomerate, that has been used in Reading and the surrounding country. South of Birdsboro is a handsome pink sandstone that has been used for building purposes in considerable quantities.

Other quarries occur along the Schuylkill Valley at Phœnixville, Valley Forge, Port Kennedy, Norristown, Bridgeport, and Fort Washington, some of considerable size, but the markets are mostly local. There are productive quarries near Doylestown and Greenoble in Bucks County.

The most productive localities for fine brownstone in the New Red area in eastern Pennsylvania are at Newtown, Yardley, and Lumberville, Bucks County. The quarry at Newtown is comparatively small, yet produces a good grade of stone that is used in fine building work. The stone is comparatively soft, has a purplish-red color, works quite freely, and looks well either in rock-face or tool-dressed surface. The quarry has been operated since 1862, and has furnished stone for use in Philadelphia and its suburbs, Trenton and Newtown.

There are two quarries within half a mile of Yardley, each of which has produced considerable stone for the local markets, Trenton, Philadelphia, and Camden. Only one of these quarries is in operation at present. Both produce a light-reddish brownstone resembling somewhat that on the New Jersey side of the Delaware at Wilburtha, all known in the market as the Trenton brownstone, which term is frequently used also to include the Stockton and Lumberville stone, farther up the Delaware. There are other smaller quarries of purely local importance in the vicinity of Yardley which are not in operation at present. The Lumberville stone, called by one of the companies "Lumberville granite," by another "Lumberville graystone," is a different character of rock from any of the other brownstones of the State. It is not properly a brownstone, much of it having a gray mixed color. Yet some of it is light brown, and it occurs in the New Red formation intercalated with red shale at what is thought to be a little lower horizon than the Newtown and Yardley quarries. The stone is much harder than the common sandstone, owing to the prevalence of siliceous cement. It closely approaches a quartzite in hardness, and might be classed as a quartzite, or at least as a very quartzitic sandstone. It differs from ordinary quartzite in having a great many grains of feldspar among the quartz grains, in some places the feldspar being in excess of the quartz. It has been used in quantity in Philadelphia for paving blocks, and has been used at various points for building stone. Its chief defects as a building stone are its hardness and lack of homogeneity in color. The first is in part compensated for by the remarkably straight grain of the rock, by means of which it can be split with great facility; the second, by quarrying in large quantities and selecting the shades. The quarries are on the Delaware division of the Lehigh Canal, on which most of the stone is shipped, but one of the companies has a wire cableway across the Delaware River to the Pennsylvania Railroad in New Jersey.

BROWNSTONE QUARRIES IN THE MAUCH CHUNK RED SHALE FORMATION.

In the Mauch Chunk Red Shale formation, in east-central Pennsylvania, in a number of places there are layers of a hard red quartzite, which is used for building and paving stone to considerable extent. It has been quarried in the vicinity of White Haven, at Laurel Run south of Wilkesbarre, and at Mocanaqua southwest of Wilkesbarre. There are two quarries about 2 miles north of White Haven, and three in active operation along the Lehigh River south of White Haven, and one or two idle ones. The product is used for flagstone, Belgian blocks, foundations, retaining walls, and superstructures. The stone is well adapted to street work, both on account of its hardness and its color. It is even harder than the Lumberville stone, and is more truly a real quartzite, as there is less feldspar among the grains and even more quartz in the cement. In a few localities there is an appreciable percentage of lime carbonate in the cement. As may be seen in the table seven pages back, the crushing strength of the stone is very high and the absorption very low. It makes a durable stone in exposed situations, like foundations and base courses, because of its slight absorption. The flagstone occurs on the outcrop almost entirely, and appears to be due to the opening of the incipient bedding seams, sometimes false bedded, by the weathering influence, the interior of the bed being massive.

The stone at Laurel Run and Mocanaqua is very similar to that at White Haven, and the uses are about the same, probably a larger proportion of it being used for building stone and less for paving than the White Haven stone. The product of all these quarries is used for the most part in Wilkesbarre, Scranton, Mauch Chunk, and smaller towns along the Lehigh Valley Railroad and the Central Railroad of New Jersey. Some has even been shipped into New York, but Wilkesbarre is the principal market. Brownstone quarries are operated at Rockwood, Somerset County, and Elwood City, Lawrence County. Gray and buff sandstones are quarried at many localities throughout central and western Pennsylvania, but have not been examined in detail by the writer.

South Dakota.—An advance from $26,100 in 1895 to $37,077 in 1896 has been made. The sandstone industry is comparatively new in the State.

Tennessee.—Sandstone valued at $4,100 was produced in 1896. The output comes from Bledsoe County. It was used for building, curbing, and flagging.

Texas.—Sandstone to the value of $97,336 was quarried in 1895; in 1896 the total value amounted to $36,000. Complaints of the depressed conditions were made by nearly all of the producers.

Utah.—A small quantity was produced in 1896. The demand was very dull.

Washington.—Sandstone to the value of $11,090 was quarried in 1896. This is somewhat below the valuation for 1895.

The following results of tests were obtained by Maj. J. W. Reilly, at the Watertown Arsenal, on Chuckanut sandstone from Whatcom County:

Tests of sandstone from the Chuckanut quarries, Washington.

Dimensions.			Sectional area.	First crack.	Ultimate strength.	
Height.	Compressed surface.				Total.	Per square inch.
Inches.	*Inches.*	*Inches.*	*Sq. inches.*	*Pounds.*	*Pounds.*	*Pounds.*
3.99	4.22	4.20	17.72	179,000	182,000	10,276
4.09	4.13	4.20	17.35	183,000	221,900	12,790
4.20	4.21	4.23	17.81	192,000	197,700	11,100

West Virginia.—The output in 1895 was valued at $40,000. This decreased to $24,693 in 1896. There is much good sandstone in the State, and some of it has made a good reputation for building purposes. Stone from Elkins, Randolph County, has been found by the Watertown Arsenal to have a crushing strength of 18,791 pounds to the square inch.

Wisconsin.—The value of the output in 1895 was $78,000, while in 1896 it was $65,017. Ordinarily prosperous conditions would have made a much larger output probable, as a number of firms failed to operate owing to lack of demand.

Wyoming.—An advance from $10,000 in 1895 to $16,465 in 1896 was made. Prospects for 1897 are said to be good.

LIMESTONE.

The total value of all limestone and lime produced by quarrymen in 1896 was $13,022,637. The figure for 1895 was $15,308,755. A falling off of somewhat over $2,000,000 is evident.

The following table shows the value of the output by States and uses for the year:

Value of limestone production in 1896, with the uses to which the stone was applied.

State.	Lime.	Building and road making.	Flux.	Total.
Alabama	$124,756	$36,300	$19,865	$180,921
Arizona	17,730	740	....	18,470
Arkansas	22,962	7,746	....	30,708
California	134,280	7,893	1,692	143,865
Colorado	14,360	5,027	45,676	65,063
Connecticut	138,158	80	707	138,945
Florida	16,107	875	....	16,982
Georgia	29,081	....	....	29,081
Idaho	5,610	52	....	5,662
Illinois	145,294	1,102,482	13,583	1,261,359
Indiana	194,916	1,337,530	126,053	1,658,499
Iowa	80,914	329,123	....	410,037
Kansas	6,576	151,385	151	158,112
Kentucky	6,672	112,877	16,418	135,967
Maine	606,998	1,000	79	608,077
Maryland	250,477	13,801	....	264,278
Massachusetts	110,537	6,616	1,469	118,622
Michigan	61,217	43,678	4,532	109,427
Minnesota	31,372	195,620	2,000	228,992
Missouri	291,268	510,247	1,453	802,968
Montana	25,100	1,200	57,627	83,927
Nebraska	640	7,285	2,730	10,655
New Jersey	109,630	591	23,992	134,213
New York	1,152,787	413,659	25,520	1,591,966
Ohio	835,594	434,208	129,610	1,399,412
Oregon	1,600	....	....	1,600
Pennsylvania	1,082,682	435,431	586,661	2,104,774
Rhode Island	11,456	....	133	11,589
South Carolina	25,000	1,000	....	26,000
South Dakota	1,126	2,000	....	3,126
Tennessee	86,913	68,403	1,860	157,176
Texas	44,005	12,710	20,537	77,252
Utah	3,835	200	5,323	9,358
Vermont	145,800	288	1,050	147,138
Virginia	84,632	8,193	89,815	182,640
Washington	80,150	....	3,592	83,742
West Virginia	32,961	5,152	21,000	59,113
Wisconsin	314,704	237,835	382	552,921
Total	6,327,900	5,491,227	1,203,510	13,022,637

The figures for "blast-furnace flux" given in this table do not correctly represent the value of all the flux quarried during the year, but only of such as was quarried and sold to the operators of blast furnaces. Some of the blast-furnace operators quarry their own limestone from quarries owned or leased by them, and as such stone does not come into the market in any way it does not appear in this table, which is intended to represent the value of the limestone output of the country in so far as the various products were sold by the producers.

Mr. James M. Swank, general manager of the American Iron and Steel Association, has kindly supplied figures showing the amount of limestone quarried by blast-furnace operators in 1896 for use as flux in their own furnaces. The amount thus quarried reaches a valuation of $685,756; these figures, added to the total given in the above table, $1,203,510, makes the total value of limestone quarried in the United States in 1896 for blast-furnace flux $1,889,266.

THE LIMESTONE PRODUCT, BY STATES, FROM 1890 TO 1896.

The following table shows the value of limestone, by States, since 1890:

Value of limestone, by States, from 1890 to 1896.

State.	1890.	1891.	1892.
Alabama	$324, 814	$300, 000	$325, 000
Arizona	(a)	....	....
Arkansas	18, 360	20, 000	18, 000
California	516, 780	400, 000	400, 000
Colorado	138, 091	90, 000	100, 000
Connecticut	131, 697	100, 000	95, 000
Florida	(a)	....	....
Georgia	(a)	....	....
Idaho	28, 545	....	5, 000
Illinois	2, 190, 607	2, 030, 000	3, 185, 000
Indiana	1, 889, 336	2, 100, 000	1, 800, 000
Iowa	530, 863	400, 000	705, 000
Kansas	478, 822	300, 000	310, 000
Kentucky	303, 314	250, 000	275, 000
Maine	1, 523, 499	1, 200, 000	1, 600, 000
Maryland	164, 860	150, 000	200, 000
Massachusetts	119, 978	100, 000	200, 000
Michigan	85, 952	75, 000	95, 000
Minnesota	613, 247	600, 000	600, 000
Missouri	1, 859, 960	1, 400, 000	1, 400, 000
Montana	24, 964	....	6, 000

a Limestone valued at $77,935 was produced in Oregon, Georgia, Florida, Arizona, South Dakota, and Wyoming. The value is included in the total.

Value of limestone, by States, from 1890 to 1896—Continued.

State.	1890.	1891.	1892.
Nebraska	$207,019	$175,000	$180,000
New Jersey	129,662	100,000	180,000
New Mexico	3,862	2,000	5,000
New York	1,708,830	1,200,000	1,200,000
Ohio	1,514,934	1,250,000	2,025,000
Oregon	(a)	....	....
Pennsylvania	2,655,477	2,100,000	1,900,000
Rhode Island	27,625	25,000	30,000
South Carolina	14,520	50,000	50,000
South Dakota	(a)	....	....
Tennessee	73,028	70,000	20,000
Texas	217,835	175,000	180,000
Utah	27,568	....	8,000
Vermont	195,066	175,000	200,000
Virginia	159,023	170,000	185,000
Washington	231,287	25,000	100,000
West Virginia	93,856	85,000	85,000
Wisconsin	813,963	675,000	675,000
Wyoming	(a)	....	....
Total	19,095,179	15,792,000	18,342,000

a Limestone valued at $77,935 was produced in Oregon, Georgia, Florida, Arizona, South Dakota, and Wyoming. The value is included in the total.

State.	1893.	1894.	1895.	1896.
Alabama	$205,000	$210,269	$222,424	$180,921
Arizona	15,000	19,810	24,159	18,470
Arkansas	7,611	38,228	47,376	30,708
California	288,626	288,900	322,211	143,865
Colorado	60,000	132,170	116,355	65,063
Connecticut	155,000	204,414	154,333	138,945
Florida	35,000	30,639	10,550	16,982
Georgia	34,500	32,000	12,000	29,081
Idaho	1,000	5,315	7,829	5,662
Illinois	2,305,000	2,555,952	1,687,662	1,261,359
Indiana	1,474,695	1,203,108	1,658,976	1,658,499
Iowa	547,000	616,630	449,501	410,037
Kansas	175,173	241,039	316,688	158,112
Kentucky	203,000	113,934	154,130	135,967
Maine	1,175,000	810,089	700,000	608,077
Maryland	....	350,000	200,000	264,278
Massachusetts	156,528	195,982	75,000	118,622

Value of limestone, by States, from 1890 to 1896—Continued.

State.	1893.	1894.	1895.	1896.
Michigan	\$53, 282	\$336, 287	\$424, 589	\$109, 427
Minnesota	208, 088	291, 263	218, 733	228, 992
Missouri	861, 563	578, 802	897, 318	802, 968
Montana	4, 100	92, 970	95, 121	83, 927
Nebraska	158, 927	8, 228	7, 376	10, 655
New Jersey	149, 416	193, 523	150, 000	134, 213
New Mexico	....	4, 910	3, 375	....
New York	1, 103, 529	1, 378, 851	1, 043, 182	1, 591, 966
Ohio	1, 848, 063	1, 733, 477	1, 568, 713	1, 399, 412
Oregon	15, 100	....	970	1, 600
Pennsylvania	1, 552, 336	2, 625, 562	3, 055, 913	2, 104, 774
Rhode Island	24, 800	20, 433	....	11, 589
South Carolina	22, 070	25, 100	....	26, 000
South Dakota	100	3, 663	4, 000	3, 126
Tennessee	126, 089	188, 664	156, 898	157, 176
Texas	28, 100	41, 526	62, 526	77, 252
Utah	17, 446	23, 696	22, 503	9, 358
Vermont	151, 067	408, 810	300, 000	147, 138
Virginia	82, 685	284, 547	268, 892	182, 640
Washington	139, 862	59, 148	75, 910	83, 742
West Virginia	19, 184	43, 773	42, 892	59, 113
Wisconsin	543, 283	798, 406	750, 000	552, 921
Wyoming	....	....	650	....
Total	13, 947, 223	16, 190, 118	15, 308, 755	13, 022, 637

The following is a consideration of the general condition of the industry in the various productive States:

Alabama.—As in many other States, there was a decline in Alabama in the value of the output in 1896, i. e., from \$222,424 in 1895 to \$180,921 in 1896. Most of this value is that of lime made by the quarrymen from the limestone quarried. Considerable was used for blast-furnace flux. The producing counties are, in order of importance, Shelby, Franklin, Lee, Calhoun, Blount, and Jackson.

Analysis of limestone from Sheffield, Franklin County, Alabama.

	Per cent.
Silica (SiO_2)	0. 50
Ferric oxide (Fe_2O_3)	1. 45
Lime (CaO)	54. 20
Magnesia (MgO)	1. 23
Carbon dioxide (CO_2)	42. 61
Total	99. 99

The following analysis was made at the Watertown Arsenal for Messrs. T. L. Fossick & Co.

Analysis of limestone from Siluria, Shelby County, Alabama.

	Per cent.
Calcium carbonate ($CaCO_3$)	99.13
Water (H_2O)	.08
Organic matter	.05
Silica (SiO_2)	.23
Alumina (Al_2O_3)	.21
Ferric oxide (Fe_2O_3)	Trace.
Magnesium carbonate ($MgCO_3$)	.12
Phosphoric acid (P_2O_5)	Trace.
Loss	.18
Total	100.00

Specific gravity, 2.84.

The following were taken from the report of the State geologist, Mr. E. A. Smith, for 1895:

Analysis of limestone, Longview, Shelby County, Alabama.

	1.	2.	3. (a)
	Per cent.	*Per cent.*	*Per cent.*
Carbonate of calcium	99.11	99.16	99.11
Carbonate magnesium	.75	.75	.14
Oxide of iron and aluminum	.13	Trace.	.21
Silica and insoluble	.39	.15	.23
Total	100.38	100.06	99.69

a By Prof. William Geuner, analytical chemist.

Specific gravity, 2.84.

Arizona.—A somewhat smaller quantity of output was realized in 1896 than in 1895, most of the value being that of lime made by the producers.

Arkansas.—The output of 1895 was valued at \$47,376; of 1896 at \$30,708. Most of the output is lime from stone quarried in Benton County.

California.—A marked decline characterized the year 1896 in this State. The value for 1895 was \$322,211; for 1896, \$143,865. The productive counties are, in order of importance, Kern, San Benito, Santa Cruz, Riverside, Santa Clara, Shasta, and Los Angeles. Most of the product is lime.

Colorado.—The output of 1895 amounted to a valuation of $116,355; for 1896 the figure was $65,063. The stone was used chiefly for blast furnace flux; it was quarried in Jefferson, Pitkin, and Chaffee counties.

Connecticut.—Most of the output of limestone comes from Litchfield County; the rest from Fairfield County. It is practically all burned into lime, the value of which was $154,333 in 1895 and $138,945 in 1896.

Florida.—A small quantity of limestone was quarried in Marion County and practically all was burned into lime, the value of which was $16,982.

Georgia.—Limestone is quarried in Catoosa, Bartow, and Polk counties. It is practically all burned into lime, the value of which in 1896 was $29,081, about double the value of the product in 1895.

Idaho.—The value of lime made in 1896 was $5,610. Practically all the limestone quarried was burned into lime. Most of it was quarried in Kootenai County.

Illinois.—This State in the past has stood first in the production of limestone for building, but in 1896 it is second to Indiana, for whose output the value was $1,658,499, against $1,261,359 for Illinois in 1896. In 1895 the value of the product in Illinois was $1,687,662. The most important producing county is Cook County; Will County comes next in importance. Small quantities are produced in quite a large number of other counties in the State. The stone is largely used for building, flagging, and curbing. The extensive quarries in the vicinity of Lemont and Joliet have been fully described in former reports.

The following are physical tests of dolomite from Niota, Illinois:

Physical tests of limestone from Niota, Illinois.

Crushing strength per square inch ....pounds..	14,120
Weight per cubic foot ....do....	161
Specific gravity	2.58
Ratio of absorption........per cent..	0.0325

Weight per cubic foot of limestone taken from quarry at Grafton, Illinois, 156 pounds.

Physical tests of limestone from Joliet, Illinois.

Position	Bed.
Specific gravity........	2.644
Ratio of absorption ....per cent..	2.73
Crushing strength per square inch ....pounds..	16,900
Weight per cubic foot........do	170

Indiana.—For its output of ornamental and building limestone Indiana is the most important and interesting State in the Union. The stone is well known as Bedford oölitic limestone, and has been quite fully described in former reports. At present it is used over practically all parts of the country, and it is popular. Prices for the stone, owing to hard times and competition, have been declining. The value of the tota output of limestone, most of which is Bedford stone, was almost the same in 1896 as in 1895; the figures were $1,658,976 in 1895 and $1,658,499 in 1896.

The following paper is the result of careful investigation and is a valuable contribution to the literature of Indiana oölitic stone. In connection with the statistical portion it should be remembered that the figures apply to oölitic limestone only, and not to the entire limestone of the State, as is the case with the total for the State already given in the tables.

THE BEDFORD OÖLITIC LIMESTONE.

By T. C. Hopkins and C. E. Siebenthal.[1]

The term "Bedford oölitic limestone," so long and so well known in commercial circles, has now been adopted as a geologic term, and designates that bed of oölitic limestone of Lower Carboniferous or Mississippian age that forms an irregular area through southwest-central Indiana, and has been quarried in at least five counties. It is now one of the best and most widely known of our building stones, having been used in at least 24 States and Territories and in 1 foreign country. Its wide reputation is due to its general usefulness in masonry, ornamentation, and monuments; its abundance; the ease with which it can be quarried and dressed, and its pleasing color and durability. The stone is properly a calcareous sandstone or freestone, differing from the ordinary sandstones in having the grains composed of lime carbonate instead of quartz and in the grains being small fossils instead of sediment transported by water from the débris of some former rock mass. It differs from other limestone in its granular texture and freestone grain.

The stone has been variously designated in geological reports as St. Louis limestone, Warsaw limestone, Spergen Hill limestone, Bedford limestone, and by more local terms—Ellettsville limestone, Salem limestone, and names of other places where it has been quarried. The term Bedford oölitic limestone is believed to be the most appropriate term, as it is the one best known commercially.

The Bedford oölitic limestone extends in a general southerly direction from Greencastle, in Putnam County, to and beyond the Ohio River into the State of Kentucky, in a belt from 2 to 14 miles wide, averaging about 5 miles, covering parts of Putnam, Owen, Monroe, Lawrence, Washington, Perry, and Crawford counties, and is quarried in large quantities in Lawrence, Monroe, Owen, and Washington counties. The towns and villages of Bedford, Bloomington, Sanders, Ellettsville, Stinesville, Romona, Salem, and Heltonville are the points around which the quarries are clustered and from which the stone is shipped. The stone

[1] While this paper is to a certain extent the work of the two writers jointly, Mr. Siebenthal, who has recently prepared a detailed map of the productive part of the oölitic limestone area, assumes responsibility for the subject-matter under the headings "Location," "Stratigraphy," and "Statistics." Mr. Hopkins is responsible for the remainder of the topics and the arrangement of the paper.

extends north of Gosport as far as Quincy, in Owen County, there being a single exposure as far north as Greencastle, Indiana, but it does not occur in commercial quantities north of Romona.

The valley of the north fork of White River at Gosport, in the north part of the oölitic area, is 570 feet above sea level, and the valley of the east fork of White River south of Bedford, south of the middle of the area, is 500 above sea level. Crests along the divide between these two forks in the vicinity of Bloomington are 900 to 950 feet high. The oölitic limestone has no topographic features distinguishing it from the other limestone. Where it forms the top rock of the ridge, the surface is gently undulating, and along the stream sources it frequently forms bold bluffs, but in both respects it is not different from other limestones of the area.

The Bedford oölitic limestone occurs in the sub-Carboniferous or Mississippian division of the Paleozoic. The associated sub-Carboniferous rocks are the Rockford goniatite limestone, the Knobstone group, the Harrodsburg limestone, the Bedford oölitic limestone, the Mitchell limestone, and the Chester or Kaskaskia group, named in order of superposition, with the oldest first.

The Harrodsburg limestone, which lies immediately below the Bedford oölitic limestone, is named from Harrodsburg, in Monroe County, where it is typically developed. It varies locally in character, being composed of massive fossiliferous crystalline limestone, blue and yellow shale, chert, compact and flaggy limestone, and in many places geodes. It varies from 60 to 90 feet in thickness.

The Mitchell limestone, immediately overlying the oölitic limestone, is named from the town of Mitchell, in Lawrence County, and consists of a series of impure limestones, calcareous shales, and fossiliferous limestones aggregating 150 to 250 feet in thickness. Specimens of lithographic limestone have been obtained from the group, but not in commercial quantities.

The Bedford oölitic limestone occurs in a massive bed varying in thickness from 25 to nearly 100 feet. The greater part of the stone is free from lamination or bedding seams. On weathered surfaces the lines of sedimentation, both true and false bedding, are brought out more or less conspicuously in several places. Sometimes even a shaly structure is developed by weathering. These are local features, as in many places the outcrop shows a comparatively regular surface, free from lamination. In almost every quarry or natural exposure there is at least one system of vertical or nearly vertical joint seams, and in many places two systems, one having a general eastward direction, the other a general north-south direction. The joint seams are rarely so numerous as to prevent the occurrence of stone in large dimensions.

Where there is a firm rock covering, the joints are seldom more than regular cracks or cleavage planes in the rock mass, but in many places where the overlying rock has disintegrated and the oölitic stone has no rock covering the weathering agencies have penetrated along the joint planes, forming irregular cave-like openings from a few inches to several feet across, which openings are now filled with the residual clay and soil, thus causing much waste and expense in quarrying. The stylolite seam, known to the quarrymen as "crow-foot" or "toe-nail," causes much waste. As seen on the face of the rock, it resembles roughly a suture joint, horizontal or nearly so, corresponding in a general way to a bedding seam, but differing from the ordinary bedding seam in the vertical jagged tooth-like projections on each side of the seam. The seam is frequently black from the collection of carbonaceous matter. These seams do not occur in all the quarries alike, some having one or two on every channel cut, some having only one or two on the whole quarry face, and a few being entirely free from them.

The Bedford stone is a granular limestone, a calcareous sand rock, in which both the grains and the cement are carbonate of lime. In the common sandstone the grains are hard and nearly angular; in the Bedford stone the grains are always soft and either round or rounded. In the siliceous sandstones the grains are harder than the cement; in the Bedford stone the cement is harder than the grains. The grains are almost entirely small fossil forms, mainly Foraminifera. These are commonly about the size of average sand grains, but in several places there are a great many larger fossils, brachiopods, gastropods, etc. The part containing these large fossils is not used for building stone, but is thrown out with the waste. The smaller forms that make up the mass of the rock vary in size in different localities, causing finer-grained stone in some localities. The finest-grained stone is the one most sought after, provided it is uniform in both grain and color.

All the Bedford stone is classed as buff, blue, or mixed. The blue is apparently the original color of at least the greater part of the stone, and is thought to be caused by the organic matter and the iron in the protoxide state, which, in contact with the oxidizing agents, give the buff color, the organic matter disappearing in gases and the iron changing to the protoxide state. There is so little of either present that the difference in color is but slight. The oxidation generally does not follow along regular lines, so that the parting is frequently marked by a very zigzag line, and in quarrying considerable stone containing the two colors intermingled, known as mixed stone, is produced, and while it is as strong and durable as any other it is nearly all thrown in the waste, as there is no demand for any but first-class stone.

The Bedford oölitic stone has been tested by most of the methods used for determining the qualities of building stone. The following table shows the specific gravity, weight per cubic foot, absorption and crushing tests made on the oölitic limestone. All of those not otherwise designated were made at the Rose Polytechnic Institute, Terre Haute, Ind. The compression tests were made upon approximately 2-inch cubes, each specimen being measured to the nearest one hundredth of an inch.

As will be seen, the tests mostly range between 4,000 and 10,000 pounds to the square inch. Counting individual tests instead of the average, there were 5 out of 50 that were more than 11,000 pounds to the square inch, the highest being as high as 13,500 pounds.

The following table give the physical characteristics of the Bedford oölitic limestone:

Physical characteristics of Bedford oölitic limestone.

No.	Operators.	Locality.	Crushing strength per square inch.	Number of specimens tested.	Specific gravity.	Weight per cubic foot.	Ratio of absorption.	Authority.
			Pounds.			*Pounds.*		
1	G. K. Perry.......	Ellettsville .	10,000	4	....	....	1-31	Rose Polytechnic Institute.
2	Matthews Bros ...	.....do	13,500	....	....	142.2	1-28	General Gillmore.
3	Indiana Steam Stone Works.	Stinesville..	5,600	3	....	....	1-17	Rose Polytechnic Institute.
4	Hunter Valley Stone Co.	Bloomington	4,100	3	....	....	1-14	Do.
5	Hunter Brothers Stone Co.	.....do	5,700	3	2.46	153.7	1-19	Do.
6	Crescent Stone Co.	.....do	5,700	3	....	....	1-15	Do.
7	Romona Oölitic Stone Co.	Romona	9,100	4	2.48	155	1-39	Do.
8	Bedford, Ind., Stone Co.	Bedford	5,600	3	2.47	154.4	1-23	Do.
9	The Chicago and Bedford Stone Co.	.....do	8,600	3	....	....	1-31	Do.
10	Bedford Quarries Co.	.....do	4,450	4	....	....	1-15	Do.
11	Twin Creek Stone Co.	Salem	9,900	3	2.51	156.9	1-31	Do.
12	Dark Hollow Stone Co.	Bedford	6,625	....	....	142.9	1-19	General Gillmore.

Samples from each of the different districts in the State were tested thoroughly at high temperatures to find their fire-resisting properties. This was done by first heating them to a temperature of 619° F. and cooling, some in air and some in cold water, all the specimens remaining uninjured. The same experiment was tried at 779° F. and 928° F. with the same result—specimens uninjured except a slight discoloration. They were then heated to the temperature of melting aluminum, about 1,157° F., when the specimens cooled in water crumbled on the lower edges, the upper edges and faces being uninjured. Some were heated to "cherry red"—about 1,500° F.—and cooled in air. Calcination was pronounced, but the specimens retained their cubical form and sharp edges.

Samples from different districts were analyzed with the results shown on the accompanying table. They show a remarkable similarity in composition over the entire area, the carbonate of lime which constitutes almost the entire rock varying between 95 and 98.27 per cent, a variation of less than 3 per cent in 16 different samples from widely separated localities.

The following table shows the chemical analyses of the Bedford oölitic limestone:

Chemical analyses of Bedford oölitic limestone.

No.	Quarry.	Calcium carbonate ($CaCO_3$).	Magnesium carbonate ($MgCO_3$).	Insoluble residue.	Iron oxide (Fe_2O_3).	Alumina (Al_2O_3).	Alkalies (K_2O, Na_2O).	Water (H_2O).	Total.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1	Bedford Indiana stone quarry	98.27	0.84	0.64	0.15		......	......	99.90
2	Hunter Valley quarry	98.11	.92	.86	.16		......	......	100.05
3	Romona quarry......	97.90	.65	1.26	.18		......	......	99.99
4	Twin Creek quarry..	98.16	.97	.76	.15		......	......	100.04
5	Hoosier quarry, buff.	98.20	.39	.63	0.39	......	......	......	99.61
6	Hoosier quarry, blue.	97.26	.37	1.69	.49	......	......	......	99.81
7	Salem quarry.........	96.04	.72	1.13	1.06		0.15	0.10	....
8	Mauckport quarry....	98.09	......	.31	.18	0.14	.40	.12	....
9	Big Creek quarry.....	93.80	4.01	.15	.64	......	......	1.09	99.69

The Bedford stone ranks among the most durable limestones in the market, proofs of which fact are (1) the chemical and physical tests showing its freedom from elements of weakness, its great uniformity of composition and texture, and its great elasticity in withstanding extremes of heat and cold; (2) the appearance of the stone in its outcrop, where it presents in many places hard compact, fairly regular faces, in some places forming perpendicular or overhanging cliffs; (3) old buildings and monuments. There are not many extremely old buildings constructed of this stone, as the first quarries were opened as late as about 1840, and it was not quarried on a large scale until after the war. The buildings that were erected at that early date, as well as those of more recent date, are all, as far as known, in a good state of preservation. In the old quarries from which the first stone was taken, there is no evidence of disintegration either on the quarry face or in the waste stone in the quarry, except that in a few places where water stands in the quarry, the stone has been observed to scale, especially where it is coarsely fossiliferous, for a few feet above the water.

There is probably not another stone in this country that works more freely and easily than the Bedford oölitic limestone. It almost rivals the French Caen limestone in this respect. The French stone is a little softer and a little more easily cut and carved, but it is also a much less durable stone. The Bedford stone is easily drilled and channeled and is thus not expensive to quarry. It is easily sawed, cut, and carved when it is first quarried. While it hardens on exposure, it never becomes so hard as granite, marble, or many of the sandstones. It is eminently adapted to carved and ornamental work, because of the ease with which it can be cut, while it is at the same time hard and durable enough to retain the marks and not to crumble under the carver's tool or on exposure.

Few building stones are more accessible than the Bedford oölitic limestone. Occurring as it does in an almost horizontal position, it outcrops over a comparatively large area, with either no covering at all or one so light that it can profitably be removed. A recently prepared geologic map of the area shows the total length of the outcrop in Owen, Monroe, and Lawrence counties to be not less than 1,600 miles. The topographic features are such that almost any point in the whole area is readily accessible by railway grade. This is practically demonstrated by the location of the different railways. The Monon Railway traverses the area from north to south over all the productive part, and that it was built before the value of the oölitic stone was known speaks well for the relative ease of building the road and for the agricultural prosperity of the region. There are also three east-west railroads and a short line known as the Belt, which serves to connect many quarries around Bedford with the other roads. There are short branch roads making switch connections with one or more of these roads running into each of the quarries.

The stone is practically all cut free on the four sides by a channeling machine. If the quarry is opened on the top of the bed, the center or the key block is removed by breaking it loose with wedges or bars at the side and lifting it out with the derrick. After the removal of the first block the subsequent blocks are removed by drilling holes along the bottom and wedging them loose, when they are lifted out with the derrick. Where the quarry is opened on the face of a cliff or a steep hillside, there is no key block, and the stone is worked back from the outcrop. In many of the larger quarries blocks from 20 to 50 feet long, 6 to 10 feet deep, and about 4 feet across are loosened. The channel cuts are commonly made either 6 feet 6 inches or 10 feet deep, but sometimes vary from these figures in order to utilize to best advantage the entire thickness of the bed and the varying thickness between the stylolyte or crowfoot seams. The stone is lifted from the quarry to the railway car by large derricks with steam-power hoists, and may be squared into mill blocks by the scabblers on the car, or it may be sent in the rough to the mill and there sawed into the desired forms for the order in hand. The saws are almost entirely the common gang saw with long iron blades made to swing to and fro across the stone, sand and water being fed under each saw automatically. One of the mills is supplied with a large diamond saw, and one company uses the wire-cable saw, first for sawing dimension stone in the yard, later for sawing stone from the quarry. In the stone mill, besides the saws, there are stone planers and headers or jointers and lathes for smoothing, trimming, and shaping the stone. The large mills are also supplied with overhead travelers, operated by steam or electricity.

The major part of the stone is used for fine dimension stone for buildings, both for face work and trimmings. It forms one of the best known and most widely used building stones in the American market, having been used in a great many public and private buildings. It has been used in at least four State houses—Indiana, Illinois, Georgia, and New Jersey—and one of the State buildings (the library) of Pennsylvania. It is known to have been used in not less than 20 court-houses in Indiana and in many Government buildings—custom-houses and post-offices—throughout the country. It finds equal favor for both face stone and trimmings, its light color harmonizing so well with many of the different colored stones throughout the country, and the ease with which it can be worked making it of double value in trimmings. A large quantity of it is used for monumental purposes, as bases for monuments or for monuments themselves. Much is used for pavements, being first sawed into flags. It makes a strong and durable pavement and does not wear slippery, as many limestones do. It is used for curbing and sewer piers and abutments, but bridge stone is mostly a cheaper grade of stone, which it does not pay to ship long distances. In a number of places it has been burned for quicklime, of which it makes a pure quality. In only two points, Salem and Romona, has this proven successful and of long duration. Limekilns at Ellettsville, Bloomington, and south and southwest of Bedford have long been abandoned and fallen into decay. In recent years it has been acquiring a local use for ballast for both railways and wagon roads.

The following table shows the commercial importance of this industry in the State. This table has been carefully prepared, and is as reliable as such tables can be made. The figures showing the capital, number of men, production, and value were necessarily obtained from the operators, but the other data were obtained by direct observation, each of the writers having visited every oölitic limestone quarry in the State. The figures do not show the total value of the stone, as much of it is shipped in the rough and sawed and cut to dimensions in the cities, at mills in Chicago, Philadelphia, New York, and elsewhere, which gives the stone an added value, but the data for which are not available.

Statistics of the Bedford oölitic limestone production in Indiana.

	North district: Romona, Big Creek, Stinesville, Ellettsville.	Middle district: Bloomington, Hunter Valley, Sanders.	Southern district: Bedford, Dark Hollow, Reeds Station, Oölitic, Peerless, Paradise, Heltonville, Salem.	Mills in Indianapolis.	Total.
Cubic feet of stone produced in—					
1895	1,295,000	1,812,716	3,030,591	....	6,138,307
1896	673,000	1,343,926	3,438,656	....	5,455,582
Value of stone produced in—					
1895	$311,875	$420,487	$771,468	$19,430	$1,523,260
1896	$165,697	$294,635	$725,883	$23,417	$1,209,632
Capital invested, 1896	$497,700	$458,400	$1,337,000	$26,500	$2,319,600
Number of men employed in—					
1895	473	424	825	62	1,784
1896	315	374	787	60	1,536
Number of quarries in operation recently	12	15	21	....	48
Number of channeling machines in operation	19	39	78	....	136
Number of channeling machines idle	11	7	11	....	29
Number of steam drills in operation	15	15	44	....	74
Number of steam drills idle	4	3	5	....	12
Number of derricks in operation	24	29	49	1	103
Number of derricks idle	6	3	8	....	17
Number of derrick turners in use	3	10	24	....	37
Number of planers and jointers	6	3	16	4	29
Number of saw gangs in operation	*a* 32	32	68	11	143
Number of saw gangs idle	9	....	9	....	18
Number of steam and electric travelers	4	3	12	1	20
Number of lathes in operation	4	0	6	....	10
Number of limekilns in recent operation	1	....	5	....	6

a One wire saw or cable way, and 1 diamond saw.

Iowa.—The output of limestone in Iowa in 1895 was valued at $449,-501; in 1896 at $410,037. There has thus been something of a decline, although not so great as might have been expected. The production of limestone is spread over many counties in the State, and the industry is on the whole an important one. Most of the output is used for building and roadmaking. The producers are quite numerous, and there are but few who are doing business on what might be called a large scale.

The following are tests of limestone from Stone City, Iowa:

Physical tests of limestone from Stone City, Iowa.

Crushing strength per square inch .... pounds..	5,150
Weight per cubic foot .... do....	136
Specific gravity	2.3

Kansas.—Production declined from $316,688 in 1895 to $158,112 in 1896. Stone quarries are quite numerous and widespread, but none of them are operated by very large concerns.

Kentucky.—The value of the limestone output declined from $154,130 in 1895 to $135,967 in 1896. The Bowling Green oölitic stone is one of interest to builders and is quite unique in character. Some of the stone gives excellent lime on burning.

Maine.—The limestone industry of Maine is almost entirely limited to Knox County, where, at Rockland and Rockport and vicinity, large quantities of lime are made for shipment to numerous points of consumption on the Atlantic coast. The value of the lime made in Maine in 1896 was $608,077. The figure for 1895 was $700,000 and for 1894 $810,089; it is thus evident that production has been decreasing for some time.

Maryland.—The total value of the limestone output in 1896 was $264,278. This represents a gain of more than $64,000 over 1895. Of this amount more than $250,000 is the value of lime made from the limestone quarried. Oyster shells are quite freely used for lime burning in this State, and some years ago, when blast furnaces were more active than at present in the vicinity of Baltimore, they were also consumed as flux.

The productive counties for limestone in the order of their importance are Frederick, Baltimore, Washington, Allegany, and Howard. The first two are about equally productive and are far in advance of the others.

The following is the result of an analysis of limestone from the vicinity of Highlands, Howard County, by Prof. H. J. Patterson:

Analysis of limestone from Howard County, Maryland.

	Per cent.
Calcium carbonate ($CaCO_3$)	77.82
Magnesium carbonate ($MgCO_3$)	3.19
Insoluble matter	13.60
Oxide of iron and alumina	5.15
Undetermined	.24
Total	100.00

Massachusetts.—Production increased from a valuation of \$75,000 in 1895 to \$118,622 in 1896. The output comes almost entirely from Berkshire County. Most of the product was made into lime.

Michigan.—The total value of the product in 1896 was \$109,427. This is quite a heavy falling off as compared with 1895, when the output was valued at more than \$300,000.

Analysis of limestone from Michigan quarries at Bay Port, Huron County.

	Per cent.
Silica (SiO_2)	3.330
Oxide of iron and alumina	1.334
Magnesium carbonate ($MgCO_3$)	.944
Calcium carbonate ($CaCO_3$)	91.538
Phosphorus and sulphur	Traces.
Organic matter and loss	2.854
Total	100.000

Analysis of limestone from quarries at Dundee, Monroe County, Michigan.

	Per cent.
Silica (SiO_2)	1.10
Calcium carbonate ($CaCO_3$)	86.80
Magnesium carbonate ($MgCO_3$)	11.60
Oxide of iron and alumina	.12
Total	99.62

Analyses of limestone from quarries at Trenton, Wayne County, Michigan (different depths.) (a)

	No. 1.	No. 2.	No. 3.
	Per cent.	*Per cent.*	*Per cent.*
Calcium carbonate ($CaCO_3$)	85.00	88.50	96.00
Magnesium carbonate ($MgCO_3$	12.36	6.93	2.10
Silica (SiO_2)	2.00	2.24	.70
Oxides of iron and alumina	Traces.	Traces.	.00
Loss	.64	2.33	1.20
Total	100.00	100.00	100.00

a By K. J. Sundstrom, chemist.

Minnesota.—Production increased from a valuation of $218,733 in 1895 to $228,992 in 1896. Reports from individual producers are more encouraging in tone than they were in 1895. The output is largely used for building and road making. The most productive county is Lesueur.

Missouri.—The limestone industry of this State is an important one, being scattered over 26 different counties, of which Jackson, St. Louis, Greene, Jasper, Marion, and Pike are the most important.

The value of the product in 1896 was $802,968, which is somewhat below that for 1895. Over $500,000 worth of the stone is used for building and road making, while nearly all the remainder represents the value of lime made.

The following analysis, made by Chauvenet & Bro., of the limestone of Hannibal, Marion County, shows the stone to be a very pure carbonate of calcium:

Analysis of limestone from Hannibal, Missouri.

	Per cent.
Silica (SiO_2)	0.08
Oxides of iron and aluminum	.40
Magnesia (MgO)	.02
Calcium carbonate ($CaCO_3$)	98.80
Total	99.30

The following were also made by Chauvenet & Bro.:

Analysis of limestone from Ralls County, Missouri.

	Per cent.
Calcium carbonate	99.64
Silica	.15
Magnesium carbonate	.21
Total	100.00

Analysis of limestone from Greene County, Missouri.

	Per cent.
Silica (SiO_2)	0.33
Oxide of iron	.21
Carbonate of calcium	99.46
Total	100.00

Montana.—The limestone output of this State was valued at $83,927, a figure slightly below that of the previous year. The product is used mainly for blast-furnace flux, and comes from Cascade and Jefferson counties, which are about equally productive.

Nebraska.—A small amount of limestone used mainly for building and road making was quarried in 1896. The most important counties are Cheyenne, Pawnee, and Gage.

New Jersey.—Most of the limestone quarried in New Jersey is burned into lime. The total value of the output in 1896 was $134,213. The most productive county is Sussex.

New York.—Thirty different counties in this State produce limestone. The total value of the output in 1896 was $1,591,966. Of this total $1,152,787 represents the value of lime made. Onondaga County produced nearly $900,000 worth of the output, while Warren County stood second with an output valued at $103,877. Quite an advance was made in 1896.

Analysis of limestone made in Onondaga County, New York.

	Per cent.
Silica (SiO_2)	5.50
Oxides of iron and alumina	1.99
Calcium oxide (CaO)	84.40
Calcium carbonate ($CaCO_3$)	4.80
Magnesium oxide (MgO)	1.80
Calcium sulphate ($CaSO_4$)	.65
Total	99.14

Analysis of limestone from Ulster County, New York.

	Per cent.
Carbonate of calcium	97.00
Silicious material	2.60
Oxide of iron	.40
Total	100.00

The following is an analysis of dolomite used in the sulphite pulp mills at Watertown, New York:

Analysis of dolomite from Natural Bridge, New York.

	Per cent.
Silica (SiO_2)	0.24
Oxides of iron and aluminum	.24
Calcium oxide (CaO)	22.43
Magnesium oxide (MgO)	29.48
Carbon dioxide (CO_2)	47.73
Total	100.12

Analysis of lime made in Washington County, New York.

	Per cent.
Silica (SiO_2)	0.23
Alumina (Al_2O_3)	1.04
Ferric oxide (Fe_2O_3)	.25
Calcium oxide (CaO)	97.64
Magnesium oxide (MgO)	.80
Total	99.96

Analysis of lime from West Coxsackie, Greene County, New York.

	Per cent.
Calcium oxide (CaO)	90.066
Magnesium oxide (MgO)	7.405
Oxides of iron and aluminum	.753
Insoluble matter	1.776
Total	100.000

Ohio.—Thirty-two counties of the State yield limestone. Of these the most important are Ottawa, Erie, Marion, and Wood, in the order named. The total value of the output in 1896 was $1,399,412, while in 1895 it was $1,568,713; there has been evidently a falling off, although, comparatively speaking, it is not serious. The value of the lime made was $835,594. Most of the remaining value is of stone devoted to building and roadmaking.

Analyses of limestone from Ohio.

Locality.	Calcium carbonate ($CaCO_3$).	Magnesium carbonate ($MgCO_3$)	Alumina (Al_2O_3).	Ferrous oxide (FeO).	Ferric oxide (Fe_2O_3).	Phosphoric anhydride (P_2O_5).	Silica (SiO_2).	Total.
	Per cent.	*Per cent.*	*Pr. ct.*	*Pr. ct.*	*Pr. ct.*	*Per cent.*	*Per cent.*	*Per cent.*
Snowflake lime-stone, Wood County	53.98	43.25	0.43	......	......	....	1.53	99.19
Fostoria, Wood County	52.00	45.26		2.70		....	Trace.	99.96
Sugar Ridge, Wood County	55.23	43.12		.65		....	.84	99.84
Williston, Ottawa County	53.90	44.82		.21		0.0011	.21	99.1411
Rex, Miami County (a)	95.60	3.93		.40		....	Trace.	99.93
Steece, Lawrence County	93.12	.98	......	......	1.92	....	3.12	99.14
Youngstown, Lawrence County	95.30	......	1.25	......	......	.017	b3.45	100.017
Tiffin, Seneca County	57.48	40.36	.10	......	.03	....	1.62	c100.00

a Made by Professor Orton. b Silicates. c Includes 0.41 per cent H_2O.

Pennsylvania.—The limestone industry of Pennsylvania during the year 1896 overtops that of any other single State. The total value of the output was \$2,104,774. Of this amount \$1,082,682 represents the value of lime made, \$586,661 that of blast-furnace flux, and \$435,431 that of stone devoted to building and road making. Thirty-seven counties of the State are productive of limestone. Of these the following are the most important, in the order given: Chester, Blair, Montgomery, Lawrence, Westmoreland, Berks, Northampton, Lehigh, Lancaster, and York. The value of the output from these counties is \$1,505,312; the value of the output from no single one of the remaining counties is as much as \$50,000. Over 1,400 separate quarries have sent in carefully prepared returns of output. Much of the lime made is used for fertilizing purposes, and consumption is decidedly on the increase. The price for such lime is 6 or 7 cents per bushel, although it is sometimes as low as 5½ cents.

The following are analyses of limestone from various localities in Pennsylvania:

Analyses of Pennsylvania limestone.

Locality.	Calcium carbonate $(CaCO_3)$.	Calcium oxide (CaO).	Magnesium carbonate $(MgCO_3)$.	Magnesium oxide (MgO).	Alumina (Al_2O_3).	Ferrous oxide (FeO).	Ferric oxide (Fe_2O_3).	Silica (SiO_2).	Phosphoric anhydride (P_2O_5).	Miscellaneous.	Total.	Authority.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	
Hanover, Adams County	83.12	....	8.23	....	0.63			0.53	0.10	*a* 4.23 *b* 3.20	99.44	
Lebanon, Lebanon County	....	38.81	....	12.85	3.75			2.80	....	....	....	
Greshville, Berks County	87.267	....	8.324	....	.810			3.48	.006	....	99.887	Prof. Andrew McCreath.
Avondale, Chester County	94.27	....	1.56	....	.26			....	....	*b* 3.91	100.00	
Bethlehem, Lehigh County *c*	....	28.78	....	20.86	1.60			3.53	.009	*d* 45.30	100.079	
Bridgeport, Montgomery County	53.491	....	45.759	....	....	....	0.45	.20	....	....	99.90	Booth, Garrett, and Blair.
Do	54.044	....	45.566	....	....	....	.20	.25	....	....	100.00	Do.
Esterly, Berks County	55.58	....	39.21	....	1.22			3.89	....	....	99.90	Mr. Chas. T. Davies.
Fairfield, Adams County	85.23	....	2.78	....	1.50			10.30	....	*e* .19	100.00	Franklin Menges, Ph. D.
Do	83.92	....	3.11	....	....	....	.60	11.85	.10	*f* .38	99.96	
Northampton, Northampton County.	93.01	....	.69	....	0.67	....	.20	4.18	....	....	98.75	Do.
Northampton County	57.88	....	39.95	....	.97			1.20	....	....	100.00	Do.
Turbotville, Northumberland County.	96.125	....	1.767	....	2.108			....	....	....	100.00	
Williamson, Franklin County	97.357	....	1.551	....	.290			.85	.002	*g* .015	100.065	

a K_2CO_3. *b* Insoluble. *c* Largely used as flux. *d* CO_2. *e* H_2O and loss. *f* K_2O. *g* Sulphur.

Limestone from Avondale varies in composition, particularly in the amount of magnesium carbonate, which is sometimes as high as 38 per cent, approaching dolomite in its constitution.

The following are analyses of lime from various localities in Pennsylvania:

Analyses of Pennsylvania lime.

Constituents.	Hanover, Adams County.	Emigsville, York County.	Dalmatia, Northumberland County. *a*
Calcium oxide (CaO)	92.00	90.68	81.38
Magnesium oxide (MgO)	3.55	1.90	1.32
Ferric oxide (Fe_2O_3)			
Ferrous oxide (FeO)	.03	.14	6.80
Alumina (Al_2O_3)			
Silica (SiO_2)	.53	.53	----------
Potassium carbonate (K_2CO_3)	4.23	----------	----------
Potassium oxide (K_2O)	----------	----------	.65
Phosphoric anhydride (P_2O_5)	----------	----------	.35
Carbon dioxide (CO_2)	----------	----------	7.05
Water (H_2O)	----------	6.75	
Undetermined	----------		----------
Insoluble	----------	----------	2.43
Total	100.34	100.00	99.98

a Analyzed by Dr. William Frear.

Rhode Island.—The production of limestone in this State has always been quite limited in amount. Quarries are operated to some extent at Lime Rock, Providence County.

South Carolina.—Limestone is produced in Cherokee County in comparatively small amount. Most of it is burned into lime, which has a good reputation for building.

South Dakota.—Very little was accomplished in this State in 1896. The stone is used for building and for burning into lime. The productive quarries are in Lawrence and Custer counties.

Tennessee.—The limestone produced in this State is about equally divided between lime burning and building. Blast furnaces quarry their own stone largely, and such production is not included in the figures given in the table for Tennessee. Eleven counties in the State produce limestone, but most of it comes from Davidson, Hamilton, Franklin, and Dickson counties.

Texas.—Production in 1896 amounted to $77,252. This is somewhat in excess of the output in 1895. Most of the product is burned into lime. El Paso and Coryell counties are the most productive. Smaller amounts are quarried in Williamson, Hood, and Travis counties.

Utah.—Small amounts of limestone were quarried in Salt Lake and San Pete counties.

Vermont.—Production of limestone fell off somewhat in 1896. Quarries were operated in Franklin, Windham, Addison, and Windsor counties.

An analysis of limestone from the quarry of Palmer & Everett, New Haven, Addison County, showed 98.37 per cent of calcium carbonate ($CaCO_3$.)

Virginia.—The production of limestone in Virginia fell off from $268,892 in 1895 to $182,640 in 1896. In the consumption of limestone for blast furnace flux, Virginia stood in third place in 1896, according to the figures of Mr. James M. Swank. The value of this flux amounted to about $350,000, including what was sold to blast furnaces and also what was quarried by the blast-furnace operators themselves. Limestone is quarried in twelve counties, of which Botetourt, Alleghany, Warren, and Shenandoah are the most important.

Analysis of limestone from Botetourt County, Virginia. (*a*)

	Per cent.
Calcium carbonate ($CaCO_3$)	98.71
Magnesium carbonate ($MgCO_3$)	.65
Oxides of iron and aluminum	.31
Silica (SiO_2)	.25
Total	99.92

a Analyzed by Dr. Henry Froehling.

Analysis of limestone from Riverton, Warren County, Virginia.

	Per cent.
Calcium carbonate ($CaCO_3$)	98.290
Magnesium carbonate ($MgCO_3$)	.462
Iron carbonate ($FeCO_3$)	.167
Silica (SiO_2)	.533
Organic matter, etc	.578
Total	100.030

Washington.—Production of limestone in 1896 slightly exceeded that of 1895. The product was almost entirely converted into lime, and was quarried in San Juan County.

West Virginia.—Limestone is quarried in Berkeley, Jefferson, Greenbrier, and Tucker counties. Most of it was converted into lime.

The following is an analysis of stone from Greenbrier County:

Analysis of limestone from Fort Spring, Greenbrier County, West Virginia.

	Per cent.
Calcium carbonate ($CaCO_3$)	96.46
Organic matter and loss	Trace.
Insoluble silicious matter	.97
Sulphur	None.
Oxide of aluminum (Al_2O_3)	1.46
Phosphoric acid	None.
Magnesium carbonate ($MgCO_3$)	1.21
Total	100.10

Wisconsin.—Twenty-eight counties of the State produce limestone. As will be seen from the table, the value of the limestone products in 1896 was something over more than half a million dollars, and less than in 1895. The output is divided in its uses between lime burning and building, somewhat more than half being converted into lime. Among the most important counties producing limestone are Calumet, Brown, Manitowoc, Fond du Lac, Waukesha, Milwaukee, and Racine.

Analysis of limestone from Calumet County, Wisconsin.

	Per cent.
Calcium carbonate ($CaCO_3$)	55.09
Magnesium carbonate ($MgCO_3$)	43.96
Silica (SiO_2)	.59
Oxide of aluminum	.36
Total	100.00