

STONE.

By WILLIAM C. DAY.

INTRODUCTION.

The data included in this report are obtained almost without exception from the individual quarrymen of the United States. Their replies are so complete and comprehensive that it is almost entirely unnecessary to make any estimates or approximations whatever. The totals given are the results of simply adding the figures returned in reply to direct inquiries. The report, therefore, could not be written until all of these replies were received and tabulated. It is hence evident that the more promptly these replies are made the sooner the results can be tabulated and the complete report written. Most of the replies are returned with very gratifying promptness, but in the case of a few what seems to be unnecessary delay retards the completion of the report. It is therefore hoped that in the future those who have needed second and sometimes even third reminders will in the interest of prompt publication make an effort to avoid unnecessary delay in making their returns.

For several years past efforts have been made to collect results of scientific, physical, and chemical tests of stone. A considerable mass of material has accumulated, and instead of scattering these results through various parts of the report, as heretofore, it has been thought wise to condense them, in so far as possible, in tabular form, thus bringing the figures relating to different products so closely together that they may be readily compared. While it may seem that a rather large mass of material has been thus acquired, it will be found on inspection that in reality comparatively little has been done. These results will be found at the end of the present report, and it is hoped that the number may be increased materially in the course of a year or two.

ACKNOWLEDGMENTS.

While the individual returns from quarrymen constitute the most important source of information used in this report, the following technical journals have been consulted, and the value of information obtained

from them is hereby acknowledged: Stone, of New York; The Monumental News, of Chicago; The Granite Cutters' Journal, of Baltimore; The Stone Trade News, of Concord, New Hampshire; The Mining Industry and Review, of Denver, Colorado, and The Journal of the Franklin Institute, of Philadelphia.

In addition to these there are many other technical papers which have been of occasional assistance. Special acknowledgments for use of publications in the above and other journals are made in the proper places in this report.

VALUE OF STONE PRODUCED IN 1897 AND 1898.

The following table shows the value of the different kinds of stone produced in the United States during the years 1897 and 1898:

Value of different kinds of stone produced in the United States during the years 1897 and 1898.

Kind.	1897.	1898.
Granite	\$8,905,075	<i>a</i> \$9,324,406
Marble	3,870,584	3,629,940
Slate	3,524,614	3,723,540
Sandstone	4,065,445	4,724,412
Limestone	14,804,933	16,039,056
Bluestone	<i>b</i> 900,000	<i>b</i> 1,000,000
Total	36,070,651	38,441,354

a Includes trap rock valued at \$927,961.

b Estimated.

This table shows a gain in the value of the output of each kind of stone except marble. For some months after the middle of April, 1898, production declined very decidedly in almost all of the producing regions, particularly in New England. This was, of course, quite largely the effect of the war. During the fall a very noticeable revival in activity of production took place generally, December being perhaps the most active month of the year in many places. The early part of the present year has shown an activity which has not been paralleled since 1892. It does not seem at all hazardous to predict for 1899 a year of gratifying prosperity.

VALUE OF STONE PRODUCT IN 1898, BY STATES.

The following table shows the value of the various kinds of stone produced in 1898, by States:

Value of various kinds of stone produced in 1898, by States.

State.	Granite.	Sandstone.	Slate.	Marble.	Limestone.	Total.
Alabama		\$27,882			\$242,295	\$270,177
Arizona		57,444			1,782	59,226
Arkansas		24,825			54,373	79,198
California	\$247,429	358,908	\$2,700	\$40,200	229,729	878,966
Colorado	25,923	89,637			109,310	224,870
Connecticut	682,768	215,733			142,657	1,040,558
Delaware	677,754					677,754
Florida					91,330	91,330
Georgia	339,311		13,125	656,808	57,803	1,067,047
Idaho				4,400	3,089	7,489
Illinois		13,757			1,421,072	1,434,829
Indiana		45,342			1,688,572	1,733,914
Iowa		7,102			524,546	531,648
Kansas		19,528			305,605	325,133
Kentucky		72,525			83,900	156,485
Louisiana		200,500				200,500
Maine	1,032,621		199,237		1,283,408	2,515,266
Maryland	317,258	13,646	82,240	120,525	433,653	967,322
Massachusetts	1,650,508	91,287	958	38,210	174,822	1,955,785
Michigan		222,376			271,523	493,900
Minnesota	79,309	175,810	400		345,685	601,204
Missouri	78,423	48,795			735,275	862,493
Montana		3,683			63,196	66,879
Nebraska					78,493	78,493
New Hampshire	683,595					683,595
New Jersey	753,513	257,217	800		146,611	1,158,141
New Mexico		3,500				3,500
New York	516,847	566,133	48,694	342,072	1,533,936	3,007,682
North Carolina	79,969	9,100			1,605	90,674
Ohio		1,494,746			1,673,160	3,167,906
Oklahoma					3,000	3,000
Oregon		7,864			7,480	15,344
Pennsylvania	237,780	478,451	2,491,756	38,373	2,746,256	5,993,616
Rhode Island	320,242				10,215	330,457
South Carolina	169,518				34,090	203,608
South Dakota	17,443	9,000			26,858	53,301
Tennessee				310,814	182,402	493,216
Texas	4,685	77,190			70,321	152,196
Utah	3,545	15,752			11,721	31,018
Vermont	1,084,218		732,684	2,067,938	174,150	4,058,990
Virginia	136,180		150,946		182,852	469,978
Washington	9,700	15,575		3,600	140,239	169,114
West Virginia		14,321			56,167	70,488
Wisconsin	175,867	80,341			698,454	954,662
Wyoming		6,382				6,382
Total	9,324,406	4,724,412	3,723,540	3,629,940	16,039,056	37,441,354
Bluestone (a)						1,000,000
Grand total						38,441,354

a Estimated.

GRANITE.

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

Value of granite product, by States, in 1898.

State.	Value.	State.	Value.
California	\$247,429	North Carolina	\$79,909
Colorado	25,923	Pennsylvania	237,780
Connecticut	682,768	Rhode Island	320,242
Delaware	677,754	South Carolina	169,518
Georgia	339,311	South Dakota	17,443
Maine	1,032,621	Texas	4,685
Maryland	317,258	Utah	3,545
Massachusetts	1,650,508	Vermont	1,084,218
Minnesota	79,309	Virginia	136,180
Missouri	78,423	Washington	9,700
New Hampshire	683,595	Wisconsin	175,867
New Jersey	753,513	Total	9,324,406
New York	516,847		

The total value of the granite output for 1898 amounted to \$9,324,406. This represents a decided gain over the last two years. This is due chiefly to increases in Connecticut, Delaware, New Hampshire, New Jersey, New York, and Vermont. In all States indications for increased business in 1899 are unquestionably good, as shown by much greater activity all over the country in the latter part of 1898 and the early part of the succeeding year. There will doubtless be larger gains in 1899 than for the last five years in most of the producing States.

The following table shows the value of the granite production in 1898, by States and uses:

VALUE OF GRANITE, BY STATES AND USES, IN 1898.

State.	Sold in rough.	Dressed for building purposes.	Dressed for monumental work.	Made into paving blocks.
California	\$18,340	\$33,143	\$24,922	\$46,103
Colorado	17,173	6,800	100	1,850
Connecticut	60,750	75,235	84,839	26,244
Delaware	1,758	1,314	600	13,171
Georgia	38,255	67,909	21,775	92,550
Maine	242,834	380,970	84,426	212,109
Maryland	87,760	65,602	10,500	33,341
Massachusetts	393,331	a 543,213	203,487	127,483
Minnesota	10,626	18,846	29,557	10,800

a Includes \$45,100 for bridge work.

Value of Granite, by States and uses, in 1898—Continued.

State.	Sold in rough.	Dressed for building purposes.	Dressed for monumental work.	Made into paving blocks.
Missouri	\$8,610	\$7,329	.....	\$29,805
New Hampshire	162,916	193,162	\$247,642	47,650
New Jersey	61,546	35,218	400	77,579
New York	30,875	159,700	46,303	6,372
North Carolina	3,795	53,130	1,168	2,120
Pennsylvania	57,640	13,327	179	30,245
Rhode Island	43,505	40,987	204,739	19,510
South Carolina	5,773	28,800	13,090	8,400
South Dakota	2,925	9,432	.....	4,600
Texas	3,570	789	.....	.....
Utah	3,293	152	100	.....
Vermont	531,634	113,922	416,878	4,446
Virginia	27,251	12,000	15,200	14,641
Washington	8,500	.....	.....	1,200
Wisconsin	4,205	12,000	56,696	43,923
Total	1,826,865	1,874,980	1,462,598	854,151

State.	Curbing.	Crushed for roads.	Riprap.	Total.
California	\$18,259	\$104,217	\$2,445	\$247,429
Colorado .....	.....	.....	.....	25,923
Connecticut	10,925	130,976	293,799	682,768
Delaware	4,299	30,417	626,195	677,754
Georgia	67,492	32,500	18,830	339,311
Maine	94,074	3,545	14,663	1,032,621
Maryland	27,747	83,888	8,420	317,258
Massachusetts	245,134	81,071	54,789	1,650,508
Minnesota	8,257	1,000	223	79,309
Missouri	23,921	4,900	3,858	78,423
New Hampshire	20,554	8,690	2,981	683,595
New Jersey .....	.....	575,818	2,952	753,513
New York	1,231	270,962	1,407	516,847
North Carolina	17,050	2,400	306	79,969
Pennsylvania	17,218	117,262	1,909	237,780
Rhode Island	3,488	1,920	6,093	320,242
South Carolina	630	23,441	89,375	169,518
South Dakota	336	.....	150	17,443
Texas	135	191	.....	4,685
Utah .....	.....	.....	.....	3,545
Vermont	12,134	5,204	.....	1,084,218
Virginia	5,533	60,500	1,055	136,180
Washington .....	.....	.....	.....	9,700
Wisconsin	4,990	54,023	30	175,867
Total	583,407	1,592,925	1,129,480	9,324,406

^a Includes \$901,487 crushed trap rock, chiefly from New Jersey, New York, and Pennsylvania.

The following table shows a decline in the value of the output of paving blocks. This branch of the granite industry does not seem to be reviving.

Value of granite paving blocks made in 1897 and 1898, by States.

State.	1897.	1898.
California	\$32,264	\$46,103
Colorado		1,850
Connecticut	76,760	26,244
Delaware	7,073	13,171
Georgia	295,005	92,550
Maine	172,637	212,109
Maryland	3,328	33,341
Massachusetts	243,750	127,483
Minnesota		10,800
Missouri	47,646	29,805
New Hampshire	26,177	47,650
New Jersey	24,006	77,579
New York	26,900	6,372
North Carolina		2,120
Pennsylvania	11,708	30,245
Rhode Island	51,646	19,510
South Carolina	4,643	8,409
South Dakota	40,030	4,600
Vermont	16,770	4,446
Virginia	20,247	14,641
Washington	1,000	1,200
Wisconsin	38,827	43,923
Total	1,140,417	854,151

For the first time in these reports on stone, trap rock has been tabulated by itself. The value of this rock for road work and its increasing production for this purpose have made this separate showing desirable.

Value of trap rock produced in the United States in 1898, by States, and uses.

State.	Rough.	Crushed for roads or ballast.	Other purposes.	Total.
California		\$50,346		\$50,346
Connecticut		76,838	\$661	77,499
Massachusetts		36,861		36,861
New Jersey	\$14,871	414,654	2,732	432,257
New York		210,700		210,700
Pennsylvania	8,160	112,088	50	120,298
Total	23,031	901,487	3,443	927,961

VALUE OF THE GRANITE PRODUCT, BY STATES, FROM 1890 TO 1898.

The following table gives the value of the granite output, by States, for the years 1890 to 1898:

Value of the granite produced by each State, 1890 to 1898.

State.	1890.	1891.	1892.	1893.
Arkansas.....	(a)	\$65,000	\$40,000	.....
California.....	\$1,329,018	1,300,000	1,000,000	\$531,322
Colorado.....	314,673	300,000	100,000	77,182
Connecticut.....	1,061,202	1,167,000	700,000	652,459
Delaware.....	211,194	210,000	250,000	215,964
Georgia.....	752,481	790,000	700,000	476,387
Idaho.....	.....	.....	.....	.....
Maine.....	2,225,839	2,200,000	2,300,000	1,274,954
Maryland.....	447,489	450,000	450,000	260,855
Massachusetts.....	2,503,503	2,600,000	2,200,000	1,631,204
Minnesota.....	356,782	.....	360,000	270,296
Missouri.....	500,642	400,000	325,000	388,803
Montana.....	(a)	51,000	36,000	1,000
Nevada.....	(a)	.....	.....	3,000
New Hampshire.....	727,531	750,000	725,000	442,424
New Jersey.....	425,673	400,000	400,000	373,147
New York.....	222,773	225,000	200,000	181,449
North Carolina.....	146,627	.....	150,000	122,707
Oregon.....	44,150	3,000	6,000	11,255
Pennsylvania.....	623,252	575,000	550,000	206,493
Rhode Island.....	931,216	750,000	600,000	509,799
South Carolina.....	47,614	50,000	60,000	95,443
South Dakota.....	304,673	100,000	50,000	27,828
Texas.....	22,550	75,000	50,000	38,991
Utah.....	8,700	.....	15,000	590
Vermont.....	581,870	700,000	675,000	778,459
Virginia.....	332,548	300,000	300,000	103,703
Washington.....	(a)	.....	.....	.....
Wisconsin.....	266,095	405,000	400,000	133,220
Total.....	14,464,095	13,867,000	12,642,000	8,808,934

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

Value of the granite produced by each State, 1890 to 1898—Continued.

State.	1894.	1895.	1896.	1897.	1898.
Arkansas.....	\$28,100				
California.....	307,000	\$348,806	\$215,883	\$167,518	\$247,429
Colorado.....	49,302	35,000	36,517	44,284	25,923
Connecticut.....	504,390	779,361	794,325	616,215	682,768
Delaware.....	173,805	73,138	67,775	272,469	677,754
Georgia.....	511,804	508,481	274,734	436,000	339,311
Idaho.....		14,560	3,037	1,900	
Maine.....	1,551,036	1,400,000	1,195,491	1,115,327	1,032,621
Maryland.....	308,966	276,020	251,108	247,948	317,258
Massachusetts.....	1,994,830	1,918,894	1,656,973	1,736,069	1,650,508
Minnesota.....	153,936	148,596	155,297	92,412	79,309
Missouri.....	98,757	128,987	107,710	97,857	78,423
Montana.....	5,800				
Nevada.....	1,600	3,200	1,250	3,050	
New Hampshire.....	724,702	480,000	497,966	641,691	683,595
New Jersey.....	310,965	151,343	204,323	561,782	753,513
New York.....	140,618	68,474	161,167	422,216	516,847
North Carolina.....	108,993	75,000	40,017	59,236	79,969
Oregon.....	4,993	1,728	2,449	1,125	
Pennsylvania.....	600,000	300,000	159,317	349,947	237,780
Rhode Island.....	1,211,439	968,473	746,277	629,564	320,242
South Carolina.....	45,899	22,083	55,320	37,820	169,518
South Dakota.....	8,806	33,279	199,977	68,961	17,443
Texas.....				3,500	4,685
Utah.....			886	3,854	3,545
Vermont.....	893,956	1,007,718	895,516	1,074,300	1,084,218
Virginia.....	123,361	70,426	95,040	88,096	136,180
Washington.....				5,800	9,700
Wisconsin.....	166,098	80,761	126,639	126,134	175,867
Total.....	10,029,156	8,894,328	7,944,994	8,905,075	9,324,406

An inspection of this table shows a decline for Maine, which was probably due—in part, at least—to the uncertainties attendant upon the war with Spain. The same general idea perhaps accounts for the slight falling off in Massachusetts. The most important granite quarries in both these States are on or near the coast.

Quite decided gains are evident for Delaware, New Hampshire, New Jersey, New York, and Vermont.

The gain in Delaware is accounted for by the production of large quantities of stone for the Delaware breakwater.

In New Jersey the production of trap rock was unusually active.

One of the most interesting features revealed by this table is that Vermont now stands second as a granite-producing State. This place in the list has heretofore been held by Maine. It is not likely, however, that Vermont will continue to hold this place uninterruptedly when conditions become entirely normal. There has been quite a falling off in Rhode Island during the past year, but the depression in this State is doubtless only temporary, and 1899 will show decided gains.

THE GRANITE INDUSTRY IN INDIVIDUAL STATES.

CALIFORNIA.

In spite of the business depression consequent upon the partial failure of both fruit and grain crops in various sections the granite industry increased in magnitude to the extent shown by the valuations, \$167,518 and \$247,429 for the years 1897 and 1898, respectively.

Much of this increase was due to greater activity in road and street improvement. Considerable stone was crushed for roads. Basalt, rather than granite proper, constitutes quite an item in the total.

Indications for 1899 are favorable.

COLORADO.

Business in Colorado in 1898 was not as good as in 1897; the value of the product in 1897 was \$44,284; in 1898, \$25,923. Conditions for 1899 are somewhat doubtful.

CONNECTICUT.

The value of the output increased from \$616,215 in 1897 to \$682,768 in 1898. An important item in the totals for both years is the stone quarried and used for breakwater construction. Included also in the total valuation is \$77,499 as the value of trap rock produced during the year.

Almost all of the producers appear to be encouraged as to the future outlook.

DELAWARE.

The rather startling increase from a valuation of \$272,469 in 1897 to \$677,754 in 1898 was due to largely augmented operations in the production of breakwater stone.

GEORGIA.

The value of the output in 1897 was \$436,000; in 1898, \$339,311. Although there has been a decline in activity of production, this does not seem likely to continue, as indications for increased output in 1899 are good.

MAINE.

Production in Maine is almost the same in value for 1897; the figures for 1897 and 1898 were, respectively, \$1,115,327 and \$1,032,621. Quite a number of the smaller operators suspended work, but some of the firms who quarried throughout the year report decided improvement over 1897. Prices seem to have been somewhat lower than in 1897. Indications in the early part of 1899 were good for markedly increased volume of business in 1899, although it does not seem likely that prices will very materially increase during the year.

MARYLAND.

The value of the output in 1897 was \$247,948, while in 1898 the corresponding total was \$317,258. Although there was an increase in output, there was some complaint of dull business among a number of the producers. The increase in output was due to larger business on the part of a few of the active concerns.

MASSACHUSETTS.

The value of the granite output falls slightly below the figure for 1897; the two values are \$1,736,069 and \$1,650,508. The production of building granite seems to have been more active than that of monumental stock. Indications for 1899 are good all over the State; reports for the early part of the year have a decidedly different tone from those of the past three or four years.

MINNESOTA.

Granite quarrying has not been very actively prosecuted for several years in Minnesota. The value of the output in 1898 shows a falling off as compared with 1897, but there are indications of improvement in volume of business for 1899. The figures for the two years were \$92,412 and \$79,309.

MISSOURI.

As in many other States, there was decided improvement in the granite business toward the end of 1898. On the whole, however, the value of the output fell behind that of 1897. The values for the two years were \$97,857 and \$78,423.

NEW HAMPSHIRE.

Granite production in New Hampshire since 1895 seems to have taken a turn in the direction of steady improvement. This is true of a number of producing regions in the State, and the industry bids fair to reach the magnitude of 1891 in the course of a year or two. The resources of the State in both building and monumental stock are varied and abundant. The value of the output in 1897 was \$641,691, while in 1898 the corresponding figure was \$683,595.

NEW JERSEY.

In the production of crystalline siliceous rocks New Jersey has made a decided upward stride in the past year. The value of the output in 1897 was \$561,782, while in 1898 it was \$753,513. Of this figure \$432,257 represent the value of trap rock, largely consumed as crushed stone for road purposes. The tendency of prices for crushed trap rock has been downward, but the volume of business has been steadily increasing. The use of harder material in the construction of the hopper of the stone crusher has resulted in lowering the cost of crushing. The superiority of trap rock for use on roads seems to be much more generally appreciated than formerly. Some of the New Jersey trap rock crushes at over 37,000 pounds to the square inch.

NEW YORK.

The value of the granite product in New York increased from \$422,216 in 1897 to \$516,847 in 1898. Somewhat less than one-half of the total value is that of trap rock for road purposes; this is being more and more demanded as the crushed stone for the roads of the State. The outlook for 1899 is much better than for several years past.

NORTH CAROLINA.

The value of the output in 1897 was \$59,236 and in 1898 \$79,969. A granite which seems to be growing in popularity as curbing material is quarried in Rowan County, near the town of Faith. Mount Airy granite is also becoming widely known through the South as both a building and monumental material. It has been shipped as far north as Pittsburg and has also been used in buildings in Philadelphia and Baltimore.

PENNSYLVANIA.

Production of granite in Pennsylvania has been somewhat irregular since 1890, when the value of the output was \$623,252. In 1897 the value was \$349,947 and in 1898 \$237,780. While comparatively little monumental granite is quarried in the State, there is an abundance of good granite for building and road purposes. Indications for 1899 are uniformly good, judging from the much greater activity in a number of localities in the latter part of 1898 and the early part of the present year.

RHODE ISLAND.

Rhode Island has for many years held a very prominent position among granite-producing States for the superiority of the granite for the finest public monuments. The stone which has been most effective in winning this reputation for the State is that quarried at Westerly and in that vicinity. Previous reports, particularly that for 1897, have set forth the excellencies of this granite for monumental work.

There was quite a decline in demand for some months after the middle of April, 1898, but in December a marked change for the better took place, giving much encouragement to some of the leading producers as to the probable output in 1899.

As a whole, the year 1898 fell behind 1897. The value of the output in the former year was \$629,564, in the latter \$320,242.

SOUTH CAROLINA.

Very much improved conditions as to demand are reported from a number of the leading producers for the year 1898. Prices, however, have not increased, and in some sections a falling off in this respect is reported.

The value of the product increased from \$37,820 in 1897 to \$169,518 in 1898.

SOUTH DAKOTA.

A decline in the output of a few of the leading producers caused a falling off in the total output from \$68,961 in 1897 to \$17,443 in 1898.

TEXAS.

But little was done in the way of granite production during the year. No very satisfactory indications as to the prospects for 1899 are at hand.

UTAH.

Although there is no dearth of valuable granite in Utah, there has never yet been a large output in the State.

VERMONT.

The history of the granite industry in Vermont for the past five years has been one of almost uninterrupted progress, so that the records of 1898 place Vermont in second position among the granite-producing States of the Union. This success has been due largely to the operations at Barre, where the stone quarried has made a national reputation as a monumental product. At this place all conditions seem to favor the economical production of monumental stock upon the large scale. Barre quarrymen seem to have been well able to stand the depression in prices for monumental stone which has characterized the past few years all over the country.

It is reported that the formation of a granite trust at Barre, which was extensively discussed in 1897, has been recently effected. An effort will be made to prevent the sale of anything but worthy material, thus protecting the reputation of the stone.

The value of the product in 1898 reached the highest figure yet attained, namely, \$1,084,218; the figure for 1897 was \$1,074,300.

VIRGINIA.

The value of the output in 1898 was \$136,180, a notable gain as compared with 1897. Reports from the various producers indicate unusually bright prospects for 1899.

WASHINGTON.

Not much has ever been done in Washington in the way of granite quarrying, but in the last two years operations which bid fair to be permanent have been undertaken. The value of the output in 1898 was \$9,700.

WISCONSIN.

The value of the granite output in 1897 was \$126,134, and in 1898, \$175,867. A decided gain is evident, and, furthermore, the indications for 1899 are better than for three or four years past. There is an abundance of fine granite in the State, as was well shown at the World's Fair.

MARBLE.

The following table shows the value of the output of marble in the United States for the year 1898, by States:

Value of marble product in 1898, by States.

State.	Value.	State.	Value.
California.....	\$40,200	Pennsylvania	\$39,378
Georgia	656,808	Tennessee.....	316,814
Idaho	4,400	Vermont	2,067,938
Maryland	120,525	Washington.....	3,600
Massachusetts.....	38,210	Total	3,629,940
New York.....	342,072		

The value of the output of marble in 1898 falls somewhat behind that of 1897, but, judging from the improvement which took place in the latter part of the year, the volume of business in 1899 will undoubtedly exceed that of either of the two preceding years. For cemetery work the output of 1898 exceeds that of 1897, but for other purposes there has been a falling off.

The following table shows the various uses to which the marble quarried in 1896, 1897, and 1898 was put:

Distribution and value of output in 1896, 1897, and 1898 among various uses.

	1896.	1897.	1898.
Sold by producers in rough state	\$583,690	\$477,856	\$690,240
Sold for outside building	1,036,163	1,074,646	968,353
Ornamental purposes	65,365	9,010	23,904
Cemetery work (monuments and tombstones)	813,146	1,547,469	1,613,742
Interior decoration in buildings	329,804	576,983	304,714
Other scattering uses	30,968	184,620	28,987
Total	2,859,136	3,870,584	3,629,940

VALUE OF MARBLE PRODUCT BY STATES.

The following table shows the purposes for which the marble of the various productive States was sold by the quarrymen in 1896, 1897, and 1898:

Value of the marble product, by uses and States, in 1896, 1897, and 1898.

State.	Rough.	Building.	Orna- mental.	Cemetery.	Interior.	Other.	Total.
1896.							
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	10,089	\$5,200				38,749
Maryland		109,000			1,000		110,000
Massachusetts	14,763	56,641		8,000	3,000	1,500	83,904
New York	69,672	365,737		41,682	4,471	3,198	484,160
Pennsylvania	3,622	28,500					32,122
Tennessee	190,163				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
1897.							
California	8,280	2,625	4,960	3,015	27,310	2,500	48,690
Colorado					82,000	17,600	99,600
Georgia	198,198	145,875		157,803	71,200	25,000	398,076
Idaho				4,500	500		5,000
Maryland		130,000					130,000
Massachusetts	1,026	58,008	300	2,300	16,481	1,000	70,721
New York	11,066	274,626		61,631	5,308	2,000	354,631
Pennsylvania		56,000		6,683			62,683
Tennessee	147,679	4,000		15,625	259,625	15,625	441,854
Vermont	111,607	402,912	3,744	1,295,912	115,159	120,895	2,050,229
Total	477,856	1,074,646	9,010	1,547,469	576,983	184,620	3,870,584

Value of the marble product, by uses and States, in 1886, 1897, and 1898—Continued.

State.	Rough.	Building.	Orna- mental.	Cemetery.	Interior.	Other.	Total.
1898.							
California	\$10,800	\$750	\$17,100	\$1,050	\$10,500	.....	\$40,200
Georgia	271,723	142,000	.....	147,000	84,700	\$11,385	656,808
Idaho	100	.....	.....	4,000	100	200	4,400
Maryland .....	.....	116,000	625	.....	3,900	.....	120,525
Massachusetts	1,210	25,000	.....	.....	12,000	.....	38,210
New York	54,696	193,464	27	74,900	3,031	15,864	342,072
Pennsylvania	75	38,700	.....	569	.....	38	39,373
Tennessee	229,483	11,000	.....	.....	66,331	.....	316,814
Vermont	108,553	441,439	6,152	1,386,142	124,152	1,500	2,067,938
Washington	3,600	.....	.....	.....	.....	.....	3,600
Total	690,240	968,333	23,904	1,613,742	304,714	28,987	3,629,940

The following table gives the production of marble, by States, for the years 1890 to 1898, both inclusive:

Value of marble, by States, from 1890 to 1898.

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
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.	1897.	1898.
California	\$13,420	\$22,000	\$4,000	\$48,690	\$40,200
Colorado .....	.....	.....	.....	99,600	.....
Georgia	724,385	689,229	617,380	598,076	656,808
Idaho	3,000	2,250	5,500	5,000	4,400
Iowa .....	.....	13,750	39,740	.....	.....
Maryland	175,000	145,000	110,000	130,000	120,525
Massachusetts .....	.....	2,000	83,904	79,721	38,210
New York	501,585	207,828	484,160	354,631	342,072
Pennsylvania	50,000	59,787	31,522	62,683	39,373
Tennessee	231,796	362,277	381,373	441,954	316,814
Vermont	1,500,399	1,321,598	1,101,557	2,050,229	2,067,938
Washington .....	.....	.....	.....	.....	3,600
Total	3,199,585	2,825,719	2,859,136	3,870,584	3,629,940

The total for 1898 shows a falling off as compared with 1897. Quite a number of the smaller operators have been inactive during 1898; at the same time indications for increased output for the future seem to be unusually good. This is shown by the exceptionally large number of new enterprises which are now just getting under way in a number of States. The tendency toward the use of marble for outside building in Vermont, New York, Pennsylvania, and Tennessee is noticeably greater than heretofore, and doubtless this tendency will show itself in figures in the course of the next few years.

THE MARBLE INDUSTRY IN THE INDIVIDUAL STATES.

CALIFORNIA.

The value of the marble output in 1898 was \$40,200, while in 1897 it was \$48,000. There are at present more firms irregularly engaged in quarrying marble in California than ever before, but, owing to lack of sufficient capital in some cases and obstacles to transportation in others, not a great deal is now being accomplished, although there is material of high grade in several localities.

A new discovery of marble, said to resemble that from Tennessee, is reported to have been made recently at the headwaters of the Gualala River, 20 miles from the seacoast, to which there is said to be a good road. The owners are Messrs. R. Powell and George Madison.

It is also said that preliminary arrangements are being made to develop this material.

GEORGIA.

The value of the product increased from \$598,076 in 1897 to \$656,808 in 1898. This indicates that business has quite markedly revived as compared with the condition in the past few years. The product is largely used for building purposes and is shipped over a wide area of the country; the stone is now a familiar one to architects, contractors, and builders, and it is favorably received as a durable as well as hard some stone.

The number of firms operating is greater at present than ever before; some of them have only lately begun operations and have not yet gotten fully under way.

MARYLAND.

The output in 1897 was valued at \$130,000; that of 1898 at \$120,525. Almost all of the stone goes for building, for which purpose it has been used for many years in Baltimore and to a less extent in other cities. The outlook for 1899 is brighter than for several years past.

MASSACHUSETTS.

While the value of the total output of marble in Massachusetts declined from \$79,721 in 1897 to \$38,210 in 1898, nevertheless the out-

look for future activity is very bright since seven different firms have recently commenced quarrying operations at Adams, Westfield, West Stockbridge, Ashley Falls, Sheffield, and Lee.

Future developments will be awaited with interest.

NEW YORK.

The value of the total output was \$354,631 in 1897 and \$342,072 in 1898. Two-thirds of the product was used in 1898 for building purposes. Prospects for 1899 seem to be much improved.

PENNSYLVANIA.

While the output of marble in this State has not greatly increased, the prospects for the future are exceedingly good, due largely to the creation of the Pennsylvania Marble and Granite Company, which has bought out the Avondale Marble Company, and is continuing the work already started by the latter firm of establishing at Avondale, Pennsylvania, the most completely equipped marble quarry in the United States. The equipment in the quarry consists partly of steam channelers of the Sullivan and Ingersoll makes, drills, gadders, a derrick of Oregon pine 105 feet 6 inches high, with a 90-foot boom, and capacity of 100 tons, operated in every movement by power, and a complete system of electric lighting for running the channeling machines at night. In the mill plant everything is operated by electrical power. Included in the plant are three of the so-called slide-motion gangs of exceptionally heavy construction, and capable of cutting with crushed steel from 5 inches per hour in the hardest granites to 24 inches in the softer stones. The tooth saw is used, and the plant has also a planer, lathe, traveling crane spanning the whole finishing department, automatic feed pumps, rubbing bed, etc.

A new quarry has been opened recently near Annville, Dauphin County. The product is used both for building and cemetery work.

TENNESSEE.

The value of the output in 1897 was \$441,954. There has been quite a decline in 1898. This was due to the temporary cessation of active operations on the part of quite a number of the smaller concerns. These, however, will doubtless resume production in 1899, as indications for improvement were reported as very evident by those who continued in business throughout the year. Building operations are now quite freely undertaken with Tennessee marble as the outside structural material. Formerly interior decoration was the purpose to which most of the output was devoted.

UTAH.

In September, 1898, the Hobbie Creek Marble Company, with headquarters at Salt Lake City, Utah, was organized and incorporated to develop marble property at Hobbie Creek, in Utah County. The

property consists of 840 acres. The stone has already been described in the report for 1896. Abundant water power is at hand so that quarry operations could be economically conducted. The quarry land is about 8 miles from the railway to Springville. The road to the railway is down grade, so that hauling would not necessarily be an unsurmountable obstacle.

VERMONT.

The value of the product in 1897 was \$2,050,229, while in 1898 it was \$2,067,938, or very nearly the same. About one-half of the product goes for cemetery work. The amount devoted to building is increasing to some extent every year.

ONYX MARBLE.

The literature concerning onyx marble is remarkably scant, and therefore the following extracts are given from a paper by Prof. Courtenay De Kalb, of the University of Missouri, Rolla, Missouri, published in Stone in November, 1898:

A sharp distinction must be drawn between the precious onyx, which is a cryptocrystalline variety of quartz, and the ordinary commercial "onyx," which is a deposit of carbonate of lime from aqueous solution. The true or precious onyx is distinguished arbitrarily from the agates by the perfect parallelism of the color bands, these bands consisting usually of alterations of white and black, white and brown, and white and red. It may be mentioned in passing that such perfect banding is so exceedingly rare that very few if any of the onyxes or cameos sold in our jewelry shops are from naturally colored stones, the artificial coloring of agates being a regular industry in Germany. The method is said to consist in saturating the more porous layers of the banded white or bluish slate-colored agate with honey, and then carbonizing this with sulphuric acid to produce the black and white variety. The red and white is produced by soaking in ferric chloride and precipitating with ammonia.

Characteristics.—The term onyx marble, as applied to calcareous deposits, must be still further limited, since many varieties exist. The general name of travertine will include all such deposits except the finely crystallized minerals calcite and arragonite. The oolites should also be excluded from this classification, although in their manner of formation these more nearly approach the true travertines. The familiar calcitic formations in caves (stalactites, stalagmites, "cave onyxes") may quite properly be classed among the travertines. That which entitles any of these to be called an onyx marble is the accidental circumstance of texture and beauty, fitting it to serve as an ornamental stone in decoration. It is therefore a commercial and not a scientific distinction.

The requisite qualities for a commercial onyx marble are: First, perfect, or nearly perfect, homogeneity of texture; second, absence of subcrystalline structure, so that no tendency to crystallization may be observable by the eye; third, freedom from porosity and cracks (although slight porosity may be corrected by "filling," and cracks, if not so deep and extensive as to weaken the stone, may often be highly colored and produce an acceptable artistic effect); fourth, translucency, the essential characteristic of a high-grade onyx marble, giving a deceptive appearance of "depth;" fifth, beauty of coloring—a matter of taste and fashion, for the most part, although the translucent white, delicate mignonette green, and fine translucent white, with dashes or veinlets of pink, are almost always in demand and bring the highest prices; and sixth, proper size of perfect blocks, the lowest limit for thickness being 1 inch, although slabs three-fourths of an inch thick are sometimes used,

with a "backing" of other material, while for superficial area the line is drawn at 1 foot square, although here again smaller sizes, if very fine in color and texture, may be marketed.

The translucent white onyx marbles are very often confounded with and sold under the name of alabaster, the true alabaster being a translucent variety of gypsum, and far less durable, owing to its greater softness, than onyx marble. Again we find in commerce a stone called "agate onyx," which is a variety of onyx marble containing more or less foreign matter, chiefly alumina, and sometimes silica, approaching the agates in appearance, but generally inclining, in part or in whole, towards opacity. While being highly ornamental, particularly in connection with dark wood interior finishing, its application is more limited than that of the finer, translucent varieties.

Price.—Before leaving the commercial side of this matter, a few additional details may prove of some importance. The highest prices are obtained by a combination of desirable physical characters with large size of blocks or slabs. The poorer grades bring sometimes as little as 50 cents per cubic foot; onyx marble, in the rough at least, being invariably sold by this unit of size, whether in blocks or sawed into slabs. From this minimum prices range upward to \$50 a cubic foot; and extremely fine blocks, suitable for columns, may command fancy figures, limited only by the size of the purchaser's purse and the vending genius of the dealer. It may be said, however, that the average size of good slabs is only 12 by 14 inches, and that slabs 18 by 36 inches and 2 by 4 feet in size are not uncommon.

Preparation.—The cost of sawing and polishing varies according as the polishing is done by the machine or the hand process. The sawing differs in no wise from that employed with other stones. The machine process is as follows: After being sawed the slabs are placed on a "rubbing bed," which consists of a circular cast-iron plate, from 8 to 15 feet in diameter, the older forms having a circular opening from 1 foot to 18 inches in diameter in the center. The plate is planed to a smooth surface and is mounted upon running gear so that it may revolve in a horizontal plane. Fixed arms, usually four in number, are sustained radially about one-fourth of an inch above the plate, either by an upright passing through the central opening or by a framework overhead (in the case of the newer solid forms of bed). The slabs of stone to be polished are placed upon the bed in front of the arms, and the bed is revolved slowly beneath them in such a direction as to hold them firmly against the arms. An abrading material, such as sand, sometimes mixed with "chilled shot" or crushed steel, with a constant supply of water, is fed upon the plate. If necessary, the stones are weighted to increase the friction. From this rubbing bed the slabs are removed to the emery bed, which is similar to the former, fine emery being used for abrasion. They are then rubbed down by hand with a fine, evenly grained sandstone, commonly called a "Scotch hone," with a sufficient supply of water, and smoothed off with pumice stone and water. The final polish is put on by rubbing the slabs upon a buffing bed, similar in form to the rubbing bed, but covered with a thick, specially prepared felt, upon which a small amount of "putty powder" (oxide of tin) is fed, to give a high gloss. The hand process consists in grinding on the rubbing bed as before, and then rubbing down by hand successively with Nova Scotia "blue stone," "red stone," "Scotch hone," and pumice stone, after which it is glossed with putty powder, or, in the case of cheaper "onyxes" and common marbles, with a mixture of two parts of oxalic acid and one part of tin oxide. This latter finish produces a sort of "skin-coat," which, upon fracture, looks as if the stone had been varnished. The edges of onyx marble tabletops, mantels, etc., are treated in this manner, even when the surface has been polished on machines. The use of common emery with white stones is objectionable, owing to its tendency to discolor them.

Occurrence.—The principal localities in this country where important deposits exist are California, Arizona, and Utah. In California the principal locality is in San Luis Obispo County, near Musick, in the Santa Lucia Mountains. Here the inclosing rock is sandstone, the onyx marble occurring in nearly vertical ledges 16 inches wide. The colors are white, with veins and "clouds" of red and smoky black or

blue. Blocks 10 feet square are said to be available. In Solano County deposits occur near Suisun, Vacaville, and elsewhere. In San Bernardino County occurs a light-brown variety, and an emerald-green shade is reported from Siskiyou County, along with others from Soda Springs and Yreka. A ledge 12 feet thick is found 25 miles from Santa Ana, in Los Angeles County, and more or less is known to exist in Kern, Placer, and Tehama counties. Almost without exception, in California, a close connection can be traced between the onyx marble deposits and hot springs, or other mineral deposits known to have resulted from such waters. In Siskiyou County they occur along with hot springs which are depositing both onyx marble and porous travertine. Eruptive rocks also abound in their vicinity. At the Suisun marble quarries is a breccia of shale, sandstone, and volcanic ash, cemented by lime, and traversed by veins and bunches of aragonite (?).

In Arizona quite similar conditions obtain. The chief deposit is on Big Bug Creek, in Yavapai County, 25 miles southeast of Prescott. It is a surface formation, occupying a series of rounded knolls several hundred acres in extent, and is found in layers varying from a fraction of an inch to several inches in thickness, interbedded with a coarse breccia of schistose, granitic, syenitic, and dioritic fragments, cemented together by a sandy calcareous matrix. The country rock is also schistose, granitic, and dioritic. The onyx marble deposits themselves consist of irregular concentric layers, thinning out unevenly, with compact layers, frequently separated by porous ones. The colors vary. Some of the finest reseda green onyx marble in the world comes from these quarries. Their beauty is enhanced often by a peculiar wavy effect of alternating light and dark shades of green, but such colors are rarely uniform throughout large blocks. Amber, ocher yellow, and white masses are found; but the characteristic of these Arizona specimens, which is sure to appear in a slab of any considerable size, is a brilliant ocherous red, running into a perfectly opaque chocolate brown, constituting the variety known as agate onyx. The more highly colored specimens often yield as much as 5 per cent of ferric carbonate. This changes to the hydrated sesquioxide, producing the brown shades and destroying the compact structure of the stone.

At Cave Creek, Arizona, is another deposit of like character, as to formation and colors. One ledge is 10 feet thick, but has been shattered by earth movements. This is on the slope of a low hill, capped with basalt. The country rock consists of schists, with dikes of acid eruptives. Throughout this region are large areas of lava mesa, underlain by volcanic tufa. These yield the calcareous waters, which also contain more or less sodium sulphate. It is also worthy of note that in the Eureka mining district of Arizona there are other deposits of travertine below similar beds of tufa and lava.

Utah is becoming a producer of onyx marble, with prospects of increasing importance, obtaining the stone from quarries to the west of Utah Lake. Directly above and in contact with the onyx marble is a blue limestone. The deposit rests upon clay, sand, and limestone. There are many evidences of earth movements, and the range in which the deposit occurs abounds in metalliferous veins. Six miles distant there is a hot spring issuing upon the surface at a temperature of 105° F. The predominating color of this onyx marble is orange, but green, pink, lemon, and other shades are procured. Slabs measuring 10 feet 6 inches by 5 feet 8 inches have been taken from these quarries and finished up. Sizes from 12 by 18 inches to 12 by 36 inches can be obtained in considerable quantities. Deposits are also reported from the vicinity of Fillmore, Millard County, ranging in color through lemon, orange, mahogany, and black. The onyx marble occurs mostly associated with limestones and quartzites, along a belt of warm springs, running through Millard, Beaver, and Iron counties. These springs occupy mainly a line of contact with eruptive rocks.

A fibrous, concretionary variety of onyx marble occurs near Rio Puerco, in Valencia County, New Mexico, and a similar deposit is reported from El Paso, Texas. This description would seem to place them among the "cave onyxes," concerning which much is heard in nearly all of the great limestone-bearing States in the Union.

These are merely stalactites and stalagmites, and in some cases masses of compact travertine, forming incrustations upon the walls and floors of caves. One of these deposits is at Eureka Springs, Arkansas, situated in the northeast part of Carroll County, near the Missouri line. A company operating works in Eureka Springs produces mostly small slabs, although mantel facings 12 by 24 inches in size are also worked out. The colors are chiefly white, with occasional tinges of red and pale green, rarely translucent, and often displaying the radiated fibrous structure so common in stalactites and stalagmites. Missouri has also produced small amounts from caves in Crawford and Pulaski counties. Sound blocks of large size, however, are infrequent, and efforts to work these deposits have proved unsuccessful. The colors are white and brown, varying from opaque to subtranslucent. Virginia has also yielded a small amount of this variety of onyx marble, coming from quarries in Rockingham County. This locality, from the insufficient accounts obtainable, would appear to offer peculiarities worthy of further investigation. There is reported to be one considerable mass of compact travertine, covered with debris, in which occur a large number of detached masses of the same material, one of which is of important dimensions, standing nearly vertical. Whether or not this is the result of a collapsed cave remains undetermined. In Missouri some of the largest masses of cave onyx are found thus in the debris of ancient caves which have fallen in. Some of these caves had been of enormous extent, so that deep ravines and very considerable valleys occupy the lines of the ruined caverns. Stalagmitic bosses may be found high up on the hillsides along these ravines, and the "float" abounds in weathered fragments of stalactites, stalagmites, and calcareous incrustations. In the process of weathering, the banded structure of the incrustations becomes very prominent, the more opaque layers projecting boldly, while the clearer layers are worn away, and acquire a chalky appearance in the body of the mass. The Arizona onyx marble weathers similarly, forming a finely striated surface, with the opaque red and brown layers protruding.

By far the most important source of onyx marble in the world to-day is the Republic of Mexico. The old localities are chiefly in the State of Puebla, between Vera Cruz and the city of Mexico. The famous "Pedrara" came from quarries near Tecali, 21 miles from the city of Puebla. Large blocks are no longer available there; but the manufacture of small ornaments by the natives is still an important industry in Puebla. Farther to the southeast, in the district of Tehuacan, is the quarry known as Antigua Salines, where the principal deposits form the face of a hill 250 feet high. Thirty-five miles west of Antigua Salines are the excellent quarries of La Sorpresa and La Mesa, the former yielding a semitranslucent to whitish stone, lacking, however, the brilliancy which distinguishes the product from Antigua Salines. These deposits are either superficial or included between masses of siliceous country rock, in the manner of veins. The old Tecali deposits are largely broken up, occurring in the form of boulders in a matrix of red clay, overlying conglomerate. The region has been much disturbed by volcanic agencies, and hot springs are abundant.

The largest onyx quarries in the world to-day are those opened in 1892 by the New Pedrara Onyx Company, of New York, in the peninsula of Lower California. They are situated in a desert 40 miles from the Pacific Ocean and 2,300 feet above its level. There are two series of deposits, 3 or 4 miles apart, the larger one showing outcrops over 20 acres. They have been formed in a shallow arroyo, or ravine, between flat-topped ridges of horizontal Cretaceous strata, overlain a few miles distant by basaltic lavas. A writer in the *Engineering and Mining Journal* says: "Within the arroyo, and immediately under and between the layers of onyx, are soft limestones and conglomerates with lime cement, probably belonging to a series of Tertiary or recent beds deposited in an irregular lake that once filled a great interior valley which occupies the medial portion of the peninsula, parallel with its shores."¹

¹ *Engineering and Mining Journal*, Vol. LVI, p. 31, July 8, 1893.

Beneath these Tertiary deposits lie granites and gneiss. The onyx marble was evidently deposited from the waters of warm springs, which extended in a line up and down the arroyo. Three distinct superimposed layers were formed, varying from 20 to 50 inches in thickness, showing that the springs were intermittent, the layers being separated by deposits of gravel cemented by lime.

Onyx marble is also reported from the State of Oaxaca, Mexico, but little is known concerning it.

Other foreign sources are Egypt and Algiers. The Egyptian quarries are at Ben-isouef, about 62 miles south of Cairo, on the Nile, and at Syout, 166 miles farther south. The stone ranges in color from white to amber-yellow, that from Syout being paler, inclining to gray. The product of both localities is known commercially as alabaster, and is of a very different quality from the Mexican varieties. It is said to be of stalagmitic origin.

The Algerian stone from the quarries of Ain-Tembaleck, near the river Issur, is found in irregular beds from a few inches to nearly 10 feet in thickness. The frequent appearance of a fibrous structure is significant.

Inferior stalagmitic marbles are quarried in many places in Italy, in the Jura Mountains in France, and in the vicinity of Stuttgart, in Germany. The caves of Gibraltar also furnish small masses of a banded brownish stalagmite, which is cut into ornaments for the tourist trade.

From the foregoing summary it appears that the deposits furnishing the superior onyx marble of commerce are found in regions which have been subjected to volcanic disturbance; that they are superficial deposits or vein-like inclosures, not connected in any manner with caves; that they are so frequently associated with active hot springs, or with other deposits manifestly resulting from hot springs, as to lead to a clear presumption that there must be a genetic relation between them and such springs; and, finally, that they occur associated with limestone rocks, or with rocks yielding large percentages of lime, such as diorite (usually 7 to 8 per cent of CaO), syenite (about 4 per cent of CaO), volcanic tufa (4 to 6 per cent of CaO), and dolerite (often as high as 10 to 11 per cent in CaO). It is also to be noted that the cave onyxes are usually either transparent or opaque, and do not exhibit that exquisite translucency recognized as the chief charm of the high-grade onyx marbles which have resulted from hot-spring deposition. The cave onyxes are, moreover, usually fibrous in structure, and are made up of concretionary layers, which can be scaled off like the skin of an onion. These latter peculiarities, however, are less likely to occur in the flat floor deposits of caves, while the concretionary structure is the more common attribute of stalagmites and the fibrous structure of stalactites. The fibrous structure may occur, however, in any situation, and is always perpendicular to the surface of deposition; and where this surface is curved, as in a stalactite or stalagmite, the fiber-like crystals extend from the center radially to the exterior, the axes passing without interruption through successive concentric layers, which may be so loosely adherent as to be split off with a light blow of the hammer.

In their other physical characters no difference seems to exist between cave onyxes and hot-spring onyx marbles. They are all calcites, as appears from their optical properties and their specific gravities, although many writers class them as varieties of aragonite. The distinction, however, is clear, both optically and by density, none of the cave onyxes or true onyx marbles rising as high as 2.9, which is the lowest limit for the density of aragonite. The large number of specimens from caves and hot-spring deposits in all parts of the United States and Mexico which the writer has examined show specific gravities ranging from 2.631 to 2.751. In composition they are exceedingly variable. The cave onyxes usually contain the smallest proportion of impurities, although the floor deposits are often rich in ferric oxide and alumina. Those from Virginia show as much as 2 per cent of magnesia, with small amounts of manganese; and one remarkable sample yielded nearly 2 per cent of lead sulphide and 4.62 per cent of antimony sulphide. A sample of green Arizona onyx marble gave 99.84 per cent of lime carbonate, and mere traces of iron and alumina.

From 2 to 8 per cent of iron and manganese is not uncommon; but, so far, no copper or nickel has been discovered in these stones, according to Professor Merrill.

The circumstances causing the great difference in texture and translucency between the cave onyxes and hot-spring onyx marbles have not yet been fully determined, and there is opportunity for trained observers to render valuable service in this particular. The greater degree of concentration of the hot solutions has been undoubtedly an important factor, and it may have been the determining one. Rapidity of flow also exerts an influence, the greater the velocity the more rapid the deposition, a circumstance first pointed out by Lyell in connection with the travertine deposits. In caves this becomes very conspicuous. On a sloping roof, for example, the stalactites increase in number and size toward the steeper portions, where the flow of the oozing waters is greatest, and incrustations form thickest upon the vertical walls, thinning out upon the floor, unless obstructions favor the building up of ledges, resulting in basins. In such cases the ledge grows upward and outward, but the incrustation again thins out upon the floor beyond, where the flow of the water is checked.

The source of the lime carbonate in cave waters is of course the surrounding limestone, taken up by the feebly solvent vadose circulation. They are consequently weak solutions, whereas the deep-seated plutonic waters, under high pressure and temperature, become highly charged with mineral matters. It is difficult to understand, however, that such waters rising from great depths should be so rich in lime carbonate and yet contain so small a proportion of other ingredients as to deposit onyx marbles running as high as 99 per cent in lime. The question seems a fair one, whether the other mineral matters may not have been deposited from these solutions in the course of their ascent, and whether they may not then have derived their lime carbonate from rocks near the surface. The frequent connection of such deposits with superficial limestones and other highly calciferous rocks tends to confirm this suspicion. That the other mineral matters should have been largely deposited below, leaving the lime carbonate still in solution, appears hardly tenable; for there is good reason to believe that mineral compounds are deposited in the inverse order of their respective heats of formation, or at least that there is an approximation to such an order, and if this be true lime carbonate should be deposited much earlier, and hence lower down, than a large proportion of the other substances which such waters would be expected to carry, its heat of formation being as high as 172.4.

It appears that the formation of the translucent compact variety of travertine, known as onyx marble, is therefore due to exceedingly rapid deposition of lime carbonate from highly concentrated solutions, probably in rapid motion. Absence of pressure seems to be another requisite, judging from the circumstance that deposits of lime carbonate occurring in deep situations, as shown in metalliferous veins, take the form of well-crystallized calcite. Further data concerning the character of the vein-like masses of onyx marble, such as those at Antigua Salines, at a considerable distance below the surface, would be desirable as bearing upon this point. Finally, it may be indicated that, guided by empirical knowledge, prospectors would do well to search for this valuable stone in volcanic regions where hot springs do now, or formerly did, exist in close association with superficial accumulations of limestones, or lime-bearing plutonic and igneous rocks.

MARBLE SLATE.

The following is an article on marble slate from the *Bautechnische Zeitung*, and translated in *Stone* for May, 1898.

Belgium exports a sort of black marble which is nothing else than prepared slate. Such black marble can be prepared in the following manner: The slate suitable for this purpose is first polished with a sandstone, so that no visible impression is made

on it with the chisel; this is the rough polish. After this it is polished finely with artificial pumice stone and finally finished with extremely light natural pumice stone. The polished surface now presents a velvet-like, soft appearance. It is allowed to dry, and the surface heated thoroughly, whereupon the finely polished surface is impregnated with a heated mixture of oil and fine lampblack. This is allowed to remain for twelve hours. According to whether the slate used is more or less gray, the process is repeated until it loses its gray appearance. Now it is polished thoroughly with emery, which is taken on a linen rag, and finally finished with tin ashes, to which is added some lampblack. After the polishing is finished, wax dissolved in turpentine, to which some lampblack is also added, is spread on, and the polished plate warmed again. It is allowed to remain some time and then rubbed off vigorously with a clean linen rag. The slate thus treated now has a deep black appearance and looks like black marble. The polish is just as durable as the latter. The polished surfaces can be etched, engraved, gilded, and silvered, just as genuine marble.

SLATE.

CONDITION OF TRADE.

The general conditions of the slate industry for the entire country are better on the whole than they were in 1897. The total number of squares of roofing slate produced is less by 89,932 than in 1897, but the value per square has increased from \$3.09 to \$3.40. This increase in price per square has not been uniform. In some places there has been a decline, undoubtedly due to some extent to unfortunate business methods in competition.

The uses for slate are extending, and the number of important articles of daily use now made from this stone is surprisingly large; the value of milled stock, which includes all forms of finished slate except roofing slate, increased in value from \$427,162 in 1897, to \$582,150 in 1898.

In the report for 1897 it was predicted that foreign trade, acquired originally as the result of labor troubles in Wales, would be retained as a permanent acquisition after tranquillity had been restored. This has so far been the case, and it still looks as though exports would continue to form an important part of the total trade.

EXPORTS.

The following table shows the ports and customs districts from which and to which slate was exported since 1893. It is evident from the table that a great and sudden increase took place in 1896. The exports for 1896 amounted to \$266,385, while those for 1895 amounted to \$38,806. In 1897 the value of the exports was more than twice that for 1896, and in 1898 the value rose to \$1,370,075, or more than five times the value in 1896. The acquisition of this export trade is an item of special interest in connection with stone, as it is the first significant attempt in this direction:

Exports of slate from United States, showing ports and customs districts from which and to which sent, from 1893 to 1898.

Ports and customs districts.	1893.	1894.	1895.	1896.	1897.	1898.
ROOFING SLATE.						
Baltimore, Maryland.....				\$9,800	\$101,581	\$170,916
Bangor, Maine.....		\$445		350		
Boston and Charlestown, Massachusetts.....	\$1,086		\$443	609	1,020	385
Newport News, Virginia.....					18,170	65,290
New York, New York.....	36,306	19,684	31,092	242,559	557,099	986,638
Passamaquoddy, Maine.....			192		120	
Philadelphia, Pennsylvania.....				2,300	94,865	136,916
Portland and Falmouth, Maine.....					270	
Brazos de Santiago, Texas.....	5					
Corpus Christi, Texas.....			105	174		1,761
New Orleans, Louisiana.....		587				
Paso del Norte, Texas.....		621				
Puget Sound, Washington.....						22
Buffalo Creek, New York.....	13,428	13,696	4,748	5,903	2,378	4,141
Champlain, New York.....	869	1,869	1,961	1,617	613	3,015
Detroit, Michigan.....			65	2,874	2,427	854
Huron, Michigan.....	200					
North and South Dakota.....	94	160				137
Vermont.....	24	133	200	139	1,569	
Total.....	52,012	37,195	38,806	266,385	780,112	1,370,075
France.....				12,000		
Germany.....			25	910	5,850	82,916
Netherlands.....					2,087	25
United Kingdom.....	1,400	4,800	3,000	197,440	695,980	1,213,377
Denmark.....						8,150
Norway and Sweden.....						270
Bermuda.....	1,016	336	1,550	2,312	1,395	167
Dominion of Canada:						
Nova Scotia, New Brunswick, etc.....	119	445	406	1,278	730	22
Quebec, Ontario, etc.....	14,615	15,858	6,974	10,533	6,977	8,147
Newfoundland and Labrador.....	32		13			
Central American States:						
Guatemala.....						1,755
Honduras.....		387				
Mexico.....	22	621	488	821	150	1,872
Miquelon, Langley, etc.....						35
West Indies:						
British.....		3,800	4,419	1,159	1,869	2,356
Haiti.....		330				26
Santo Domingo.....			10			
Spanish, Cuba.....		2,643	3,258	90		673
Colombia.....				259	100	
Guianas:						
British.....		712	702	440	165	600
Dutch.....	3,145		340		1,640	1,325
Peru.....	405					
Uruguay.....				417		807
China.....						110
East Indies—British.....				1,628	819	550
British Australasia.....	30,362	7,000	17,363	34,970	60,604	44,642
Hawaiian Islands.....				245	166	
British Africa.....	896		258	1,883	1,598	2,218
Portuguese Africa.....						42
Total.....	52,012	37,195	38,806	266,385	780,112	1,370,075

PRODUCTION.

The following table shows the output of roofing and milled slate in 1898:

Value of slate product in 1898, by States.

State.	Roofing slate.		Other purposes than roofing: value.	Total value.
	Squares.	Value.		
California	400	\$2,700	.....	\$2,700
Georgia	3,450	13,125	.....	13,125
Maine	29,834	131,752	\$67,483	199,237
Maryland	18,332	80,786	1,454	82,240
Massachusetts .....	.....	.....	958	958
Minnesota	100	400	.....	400
New Jersey	200	800	.....	800
New York	7,160	46,744	1,950	48,694
Pennsylvania	571,256	2,007,735	394,021	2,401,756
Vermont	241,762	612,902	119,782	732,684
Virginia	43,745	142,446	8,500	150,946
Total	916,239	3,129,390	594,150	3,723,540

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	1895	\$3.23
1891	3.49	1896	3.36
1892	3.56	1897	3.09
1893	3.55	1898	3.42
1894	3.11		

The average value per square for 1898 is the highest figure reached since 1893. The foreign demand has doubtless had much to do with the rise in value.

The following table shows the value of the production of slate, by States, during the years 1890 to 1898, inclusive:

Value of slate, by States, from 1890 to 1898.

State.	1890.			
	Roofing slate.	Value.	Other purposes than roofing; value.	Total value.
	<i>Squares.</i>			
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.
	<i>Squares.</i>			
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
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 1898—Continued.

State.	1892.			
	Roofing slate.	Value.	Other purposes than roofing; value.	Total value.
	<i>Squares.</i>			
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.
	<i>Squares.</i>			
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 1898—Continued.

State.	1894.			
	Roofing slate.	Value.	Other purposes than roofing; value.	Total value.
	<i>Squares.</i>			
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	118,831	19,300	138,131
Total.....	738,222	2,301,138	489,186	2,790,324

State.	1895.			
	Roofing slate.	Value.	Other purposes than roofing; value.	Total value.
	<i>Squares.</i>			
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 1898—Continued.

State.	1896.			
	Roofing slate.	Value.	Other pur- poses than roofing; value.	Total value.
	<i>Squares.</i>			
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

State.	1897.			
	Roofing slate.	Value.	Other pur- poses than roofing; value.	Total value.
	<i>Squares.</i>			
California	1,000	\$7,000	.....	\$7,000
Maine	38,367	161,262	\$39,855	201,117
Maryland	11,592	53,049	890	53,939
Minnesota	400	1,000	500	1,500
New Jersey	250	775	.....	775
New York	9,197	52,799	1,000	53,799
Pennsylvania	657,692	2,034,958	330,341	2,365,299
Vermont	244,575	656,114	39,701	695,815
Virginia	38,375	130,495	14,875	145,370
Total	1,001,448	3,097,452	427,162	3,524,614

Value of slate, by States, from 1890 to 1898—Continued.

State.	1898.			
	Roofing slate.	Value.	Other purposes than roofing; value.	Total value.
	<i>Squares.</i>			
California.....	400	\$2,700	.....	\$2,700
Georgia.....	3,450	13,125	.....	13,125
Maine.....	29,834	131,752	\$67,485	199,237
Maryland.....	18,332	80,786	1,454	82,240
Massachusetts.....	.....	.....	958	958
Minnesota.....	100	400	.....	400
New Jersey.....	200	800	.....	800
New York.....	7,160	46,744	1,950	48,694
Pennsylvania.....	571,256	2,097,735	394,021	2,491,756
Vermont.....	241,762	612,902	119,782	732,684
Virginia.....	43,745	142,446	8,500	150,946
Total.....	916,239	3,129,390	594,150	3,723,540

THE SLATE INDUSTRY IN INDIVIDUAL STATES.

CALIFORNIA.

While the production of slate in California fell off from a total valuation of \$7,000 in 1897 to \$2,700 in 1898, it would be a mistake to ascribe the decline to a falling off in demand; it was due rather to a transfer of one of the leading quarries to other hands and a consequent temporary cessation of operations. The statement was made in the case of one of the active operators that a much larger output could have been secured if a greater amount of operating capital had been available during the year. The prospects for 1899 are better than for several years.

GEORGIA.

Although there is an abundance of excellent slate in Georgia, particularly at Rockmart, quarrying operations fluctuate in activity from year to year, so that while in some years almost nothing is accomplished, in others production is quite brisk. In 1896 the value of the entire output was \$20,388, while in 1897 very little was quarried. Demand for slate in the South has never yet been very active. The value of the output in 1898 was \$13,125.

MAINE.

Production in 1898 amounted to a total valuation of \$199,237, or practically the same as in 1897. The product is about equally divided between roofing and milled stock.

The fine quality of Maine slate is well known, and there are at present twice as many producers of it as there were a few years ago.

MARYLAND.

The Maryland slate quarries are near the State line dividing this State from Pennsylvania, and they include most of what is known as the Peach Bottom slate region of York County, Pennsylvania, and Harford County, Maryland. Nearly all the product goes for roofing, and amounted in value in 1898, to \$82,240. The figure for 1897 was \$53,939.

MASSACHUSETTS.

This State does not regularly produce slate, but, as in the year 1898, occasionally yields a trifling amount. At the present time (March, 1899) there is no quarrying concern in active operation.

NEW JERSEY.

The Pennsylvania slate belt extends just over the line into New Jersey. This fact accounts for a small annual production in this State.

NEW YORK.

New York State furnishes the only cherry red slate quarried in the world. The amount of this exceptional material in New York is not large, and owing to its attractive and unique color it commands the highest price for roofing purposes of any slate in the country. The value of the output in 1898 was \$48,694. Since August, 1898, prices declined somewhat.

PENNSYLVANIA.

Two-thirds of the slate output of the United States is taken from quarries in Pennsylvania. The total value of all slate produced in the United States in 1898 was \$3,723,540; to this total Pennsylvania contributed \$2,491,756. Most of the product goes for roofing, but the value of milled stock is now rapidly increasing. The figure for value of milled stock in 1897 was \$330,341; in 1898 it was \$394,021. The industry is in a flourishing condition at present, owing in no small degree to the export trade, which began in 1896 and has continued since because of the increasing popularity of American slate abroad. Not only has foreign trade been retained, but the very general opinion expressed by producers is that exports have exceeded former years. Domestic trade has been but little better, although prices have improved on the whole.

VERMONT.

The total value of the product in 1897 was \$695,815; in the past year this increased to \$732,684. As was also the case among Pennsylvania producers, domestic trade was but little better, while exports were noticeably greater than in 1897. Prices declined somewhat during the year; for the past four years complaints about prices have been prevalent.

VIRGINIA.

The value of the output increased from \$145,370 in 1897 to \$150,946 in 1898. Most of the product is in the form of roofing slate, although a little milled stock is also turned out. Virginia slate is exported in about the same proportion as the product from Pennsylvania and Vermont.

SLATE BELT OF EASTERN NEW YORK AND WESTERN VERMONT.

The following is an abstract of a paper entitled The Slate Belt of Eastern New York and Western Vermont, by Prof. T. Nelson Dale, published in the Nineteenth Annual Report of the United States Geological Survey, Part III. The paper is a most valuable contribution to the literature of slate from both the scientific and the technological standpoint, and those interested, either specially in the slate of the region discussed or in slate in general, are referred to the complete paper.

In order that quarrymen generally, as well as slate producers, may profit by the economic features of this paper, they are presented here.

LOCATION AND AREA OF THE SLATE BELT.

The slate belt of eastern New York and western Vermont lies between the Taconic range on the east and Lake Champlain and the Hudson on the west, and chiefly between the Hoosic River, one of the eastern tributaries of the Hudson, on the south, and the towns of Benson and Hubbardton, in Vermont, on the north, or between latitudes $42^{\circ} 58'$ and $43^{\circ} 45'$, a stretch of about 55 miles; but slate is said to continue as far north as Cornwall, making an extreme length of 68 miles. As, however, good slate is hardly obtainable south of Shushan and Greenwich, in Washington County, the actual length of the slate belt is about 45 miles. Its width at the north is about 11 miles and at the south about 6 miles, averaging a little over 7 miles. The area in which slate of not a little economic value is known covers, therefore, about 320 square miles, which lie within the counties of Washington, New York, and Rutland, Vermont.

The slates are green of various shades, purple, variegated (that is, mixed green and purple), red, and also black. They are used for roofing and other purposes.

PREVIOUS WORK OF GEOLOGISTS.

Without undertaking to enumerate all the minor papers relating to portions of this region, attention is directed to the following more important and general pieces of work: That of Prof. Ebenezer Emmons and that of Prof. William W. Mather on the geological survey of New York State, published in 1843; that of Messrs. Hitchcock and Hager in their report on the geology of Vermont, published in 1861, which also included a geological map; Logan and Hall's general map of Canada and the northeastern part of the United States, dated 1866, which embodied the results both of the New York State survey and of the explorations of the Canadian survey within the United States; Prof. C. H. Hitchcock's geological map of New Hampshire and Vermont, 1877, in which all previous work in Vermont was correlated; the same author's sections across New Hampshire and Vermont, published in 1884; and finally Mr. C. D. Walcott's map of the Taconic region, published in 1888. Mr. McGee's map of New York State, compiled under the direction of Mr. James Hall in 1894, simply incorporated Mr. Walcott's work and left some doubtful areas blank.

While the presence of the Lower Silurian rocks was early recognized, Cambrian rocks were at first confounded with them. It was not until long after the discovery of an older series that it was placed in its present stratigraphical position in the Lower Cambrian. The work of the early surveys had the merit of covering a large territory in a general way at little expense. Nothing approaching scientific satisfactoriness was done, however, till the publication of Mr. Walcott's paleontological map in 1888, in which Cambrian and Silurian fossil localities were indicated, so that the geological boundaries of previous surveys could be corrected thereby; but even this still lacked an adequate topographical base. In 1893 Kemp and Marsters described the dikes of the Lake Champlain region, and included two of those of the slate belt.¹ As to economic geology, little has been done hitherto beyond the publication of several incomplete analyses of the slates and a few brief references to the slate quarries. These are mostly in the Vermont Survey Report. But the statistics of slate production have been for a number of years systematically collected and published by the Division of Mineral Resources of the United States Geological Survey.

¹The trap dikes of the Lake Champlain region, by J. F. Kemp and V. F. Marsters: Bull. U. S. Geol. Survey, No. 107.

The following analyses were made by Dr. W. F. Hillebrand of the chemical laboratory of the United States Geological Survey:

THE "SEA-GREEN" ROOFING SLATE.¹

CHEMICAL ANALYSES.

Constituents.	Specimens. ²			
	A.	B.	C.	D.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
SiO ₂ (silica)	67.76	62.37	59.84	65.29
TiO ₂ (rutile; titanium dioxide) ...	.71	.74	.74	.....
Al ₂ O ₃ (alumina)	14.12	15.43	15.02	.....
Fe ₂ O ₃ (ferric oxide) .....	.81	1.34	1.23	.....
FeO (ferrous oxide)	4.71	5.34	4.73	.....
MnO (manganese oxide) .....	.10	.22	.34	.....
NiO, CoO (nickel and cobaltous oxide)	Trace?	Trace.	Trace.	.....
CaO (lime) .....	.63	.77	2.20	.....
BaO (baryta) .....	.04	.07	.09	.....
MgO (magnesia)	2.38	3.14	3.41	.....
K ₂ O (potassa)	3.52	4.20	4.48	.....
Na ₂ O (soda)	1.30	1.14	1.12	.....
Li ₂ O (lithia)	Str. tr.	Trace.	Str. tr.	.....
H ₂ O (water below 110° C.) .....	.23	.34	.41	.....
H ₂ O (water above 110° C.)	2.98	3.71	3.44	.....
P ₂ O ₅ (phosphoric oxide) .....	.07	.06	.09	.....
CO ₂ (carbon dioxide) .....	.40	.87	2.98	.....
FeS ₂ (pyrite) .....	.22	.06	.05	.....
SO ₃ (sulphuric oxide)	Trace.	Trace.	Trace.	.....
C (carbon)	None.	Str. tr.	Trace.	.....
Fl (fluorine) .....	.....	.....	.11	.....
Total	100.07	99.80	100.28	.....
S (total sulphur above) .....	.12	.032	.024	.....

A (=D. XIV, 1895, 230a), Rising & Nelson's quarry No. 2, West Pawlet, Vermont; 13-foot bed. B (=D. XIV, 1895, 225f), Griffith & Nathaniel's quarry, 9 miles north of A, South Poultney, Vermont. C (=D. XIV, 1895, 256c), Wm. H. Hughes's quarry No. 10 (Brownell), 2 miles north of A, Pawlet, Vermont. D (=D. XIV, 1895, 35, 1), Auld & Conger's quarry, 8 miles north of A, in Wells, Vermont; 23-foot bed. Determination of silica only. These are all from the West Pawlet and South Poultney belt.

Specific gravity: C, 2.7910; D, 2.7627.

¹ Lower Cambrian, Horizon B, Olenellus zone.

MICROSCOPIC ANALYSIS.

The so-called "sea-green" slate, when freshly quarried, varies from a light gray to a slightly greenish gray. In some beds it is crossed by ribbons (beds) of a dark gray. The fresh cleavage surface has a more or less waxy luster. After a few years of exposure to the atmosphere the color assumes more or less of a yellowish-brown tinge. Cold dilute hydrochloric acid applied to the edge produces a slight effervescence.

Sections transverse to the cleavage show, in ordinary light, a very fine and regular cleavage, sometimes crossed by obscure traces of bedding, angular transparent grains, green (dichroic) scales, minute opaque spherules covered with crystal points, and from 0.003 to 0.02 mm. in diameter, which, under incident light, glisten like pyrite, some irregular opaque grains, dull yellowish under incident light, and of doubtful character, and, finally, a few lenses of transparent mineral grains. In some transverse sections a few "slate needles" (rutile, TiO_2) are visible.

The most noticeable feature of transverse sections under polarized light is that in rotation they become, so far as the matrix is concerned, alternately dark and light, behaving like a single mineral. The slate consists mainly of brilliant interlacing, but more or less parallel fiber-like scales of mica (muscovite-sericite), which produce the effect of a mass of gold embroidery. These fiber-like scales of mica surround and inclose more or less angular grains of quartz, with their longer axes parallel to the cleavage. Such grains measure from 0.052 to 0.347 mm. in length by 0.0043 to 0.035 mm. in width. Their usual dimensions are 0.035 by 0.013 mm. Perhaps less abundant than the quartz, although this proportion varies greatly, are carbonate rhombs and plates.

Scales of a chlorite like that already referred to in the Olive grit (Horizon A) occur interleaved with muscovite or talc. The scales under polarized light vary from a prussian or plum blue to a violet or olive, while the delicate bands polarize in brilliant hues. The entire scales measure up to 0.130 mm. In sections made at right angles to the grain and transverse to the cleavage these scales frequently lie at a very high angle or a right angle to the cleavage. The mineral called "a chlorite" in these descriptive notes has the following characteristics: Under incident light the scales are dark and stand out distinctly from the matrix, as do also any large scales of muscovite. In ordinary light the scales are dichroic (pale green and slightly greenish yellow), and frequently have delicate white bands parallel to their cleavage. Under polarized light such scales become bright lavender (violet) or a prussian blue or an olive, and extinguish parallel to the cleavage, while the white bands polarize in the brilliant colors characteristic of talc and muscovite. These scales occur both in the slate and the Olive grits. Other green dichroic scales, however, cut parallel to their cleavage are under polarized light almost isotropic. Still other pale-green scales, not perceptibly dichroic, remain dark or banded with

prussian blue throughout one revolution. A coating of an undoubted chlorite from a slickensided surface in purple slate in Castleton, when scraped off and examined under the microscope, showed the dichroism distinctly, and under polarized light remained green in a complete revolution. It gelatinized in boiling sulphuric acid. Attempts to dissolve the "chlorite" scales of the thin sections of slates in hot sulphuric acid were not successful, possibly owing to wrong manipulation. The double refraction of the bands of muscovite was, however, more conspicuous after than before the application of the acid. The usual appearance of the mineral in the slate sections is the first described above. The sections are transverse to the foliation of the mineral, and the differences in colors may then be due to differences in the thickness of the sections or to a slight obliquity of the scale within the slate.

There are also muscovite scales, often bent, possibly fragmental like the quartz, occasional fragments of feldspar (lime-soda-feldspar) up to 0.043 by 0.052 mm. and, more rarely, small fragments of zircon. Apatite was not detected, although, judging from the analyses, it may occur. The lenses of transparent grains prove under polarized light to consist of cryptocrystalline quartz.

Sections parallel to the cleavage in ordinary light show a pale brownish indefinite groundmass with irregular transparent fragments and rhombs. Some of the rhombs have a colorless, some a black, nucleus, which does not seem to be pyrite. Pyrite occurs as before. Under higher powers vast numbers of needle-like crystals, "slate needles" (rutile), appear. These needles measure from 0.0017 to 0.009 mm. in length, rarely attaining 0.012, and 0.0024 mm. in diameter. They average from about 1,000 to 1,850 per square millimeter of the sections, which amounts to from about 25,000 to about 47,000 to the square inch. These sections, under polarized light, do not polarize as one mineral, but bring out on a dark groundmass¹ the quartz fragments, plagioclase fragments, and the carbonate plates and rhombs. These rhombs measure from 0.003 to 0.015 and even to 0.052 mm. in diameter. They sometimes consist of two crystals, an inner rhomb and an outer one, but having a different orientation, possibly in twinned position. In some cases the central rhomb has fallen out, leaving a black center under crossed nicols. Here and there a muscovite scale appears and under high power the orange-yellow rutile needles. The conspicuous features in parallel sections under polarized light are the brilliantly double refracting carbonate rhombs and the quartz grains.

THE DISCOLORATION OF THE SEA-GREEN SLATES.

As is well known, the sea-green slates pass, on a few years' exposure, from a greenish gray to a brownish gray. In exceptionally bad beds the change is from a pale bluish (chloritic) green to a dark yellowish

¹ Some European writers insist on the presence of an isotropic mineral in roofing slates.

brown, producing a marked contrast when fresh and weathered pieces are placed side by side. In those slates in which discoloration is pronounced the fresh slate surface effervesces somewhat rapidly with cold dilute hydrochloric acid, as they all do slightly on the edges. In order to ascertain the cause of the discoloration a thin section was made across the discolored surface of a slate which had been exposed for three years. The section showed that while the rhombs of carbonate within the body of the slate were transparent in ordinary light, those at the edges were changed to the color of burnt sienna, i. e., to the characteristic limonitic staining. These particular rhombs measured 0.047 mm. in diameter. Dr. Hillebrand succeeded in showing this still better. A cleavage surface, discolored by a three-years' exposure, was affixed to the glass slide and the other side was ground down the requisite amount. This section showed a multitude of rhombs—from 0.004 to 0.030 mm., but generally from 0.008 to 0.013 mm. in diameter—entirely or partially altered to limonite. In some cases there was a yellowish-brown zone of alteration surrounding an unaltered nucleus. By applying dilute hydrochloric acid to a section (parallel to cleavage) of the undischolorated slate placed under polarized light the brilliant rhombs are dissolved more or less rapidly and the dark matrix with a few mica scales alone remains. Dr. Hillebrand regards the rhombs as an isomorphous mixture of dolomite and siderite, i. e., a carbonate of lime, magnesia, and iron, in which the iron oxidizes into limonite. His chief reason for supposing them to be a dolomite rather than calcite is their behavior toward cold acids, which, together with other reasons, are detailed in his remarks appended to this paper. Calcite, however, is abundant both in the veins and in the beds of quartzite in the slate. Bischof attributed the discoloration of certain German slates to the formation of limonite from a protoxide, and endeavored to restore their original color by immersing them in dilute hydrochloric acid, but he found that although this proved effective, new discoloration took place within a short time.¹

"HARD" AND "SOFT" SEA-GREEN SLATES.

The microscopic and chemical tests to determine the cause of this difference were inconclusive. It seems probable, however, that the "soft" slates are due to a greater percentage of carbonate and the "hard" ones to the large size of the quartz grains rather than to the greater percentage of silica.

¹Lehrbuch der chemischen und physikalischen Geologie, Vol. II, pp. 350-351, footnote. The only way to prevent the discoloration would be to coat the slates with something which would protect them from oxidation.

THE "UNFADING GREEN" ROOFING SLATE.¹

CHEMICAL ANALYSES.

The following analyses were made in the laboratory of the United States Geological Survey by Dr. W. F. Hillebrand:

Chemical analyses of green roofing slates.

Constituents.	Specimens. ^a	
	E.	F.
	<i>Per cent.</i>	<i>Per cent.</i>
SiO ₂ (silica)	59.27	59.48
TiO ₂ (titanium dioxide, rutile) .....	.99	1.02
ZrO ₂ (zirconia)		Trace?
Al ₂ O ₃ (alumina)	18.81	18.22
Fe ₂ O ₃ (ferric oxide)	1.12	1.24
FeO (ferrous oxide)	6.58	6.81
MnO (manganous oxide) .....	.13	.07
NiO (nickelous oxide)	Trace?	Trace.
CoO (cobaltous oxide)	Trace?	
SrO (strontia)		Trace?
CaO (lime) .....	.42	.56
BaO (baryta) .....	.05	.05
MgO (magnesia)	2.21	2.50
K ₂ O (potassa)	3.75	3.81
Na ₂ O (soda)	1.88	1.55
Li ₂ O (lithia)	Trace.	Trace.
H ₂ O (water below 110° C.) .....	.32	.17
H ₂ O (water above 110° C.)	3.98	4.65
P ₂ O ₅ (phosphoric oxide) .....	.11	.10
CO ₂ (carbon dioxide) .....	.21	.39
FeS ₂ (pyrite) .....	.15	.13
SO ₃ (sulphuric oxide)	Trace.	
C (carbon)	None.	None.
Fl (fluorine) .....		.08
Total	99.98	100.23
S (total sulphur included above) .....	.08	.07
Specific gravity of E	2.795	

^a E (=D. XIV, '95, 314F), Eureka quarries, 3½ miles north of Poultney, in Poultney Township, Vermont. F (=D. XV, '96, 645a), Valley Slate Company quarry, 2½ miles north of Poultney, in Poultney Township, Vermont.

¹ Lower Cambrian, Horizon B; Olenellus zone.

MICROSCOPIC ANALYSIS.

The "unfading green" slate is a pale greenish gray with less luster on the cleavage surface than the sea green. Several years' exposure produces little or no change in color.¹ Cold dilute hydrochloric acid does not produce any effervescence when applied to the hand specimen. Sections across the cleavage in ordinary light show considerable inequality in texture, coarser and finer bands alternating with one another, the coarser with imperfect cleavage. Even where the cleavage is more regular there is still much irregularity in the size of the particles. There are not a few grains and lenses of pyrite, some irregular opaque grains, dull yellowish in incident light and of doubtful character, green dichroic scales up to 0.039 by 0.006 mm., which, in sections transverse to "the grain," lie edgewise across the cleavage, and finally, slate needles (rutile) from 0.003 to 0.008 mm. in length, and some granular lenses.

Similar sections under polarized light show a matrix of fibrous muscovite (sericite), polarizing as one mineral and inclosing angular quartz grains from 0.013 to 0.043 by 0.004 to 0.017 mm., rarely 0.07 by 0.017 mm., with inclusions; also rarely grains of plagioclase. There is much less carbonate than in the "sea-green" slate, some brilliant scales of muscovite. In sections transverse to the grain many of the more minute scales of muscovite lie at right angles to the cleavage. Finally, some lenses of cryptocrystalline quartz.

Sections parallel to the cleavage, under ordinary light, show the usual brownish matrix and abundance of slate needles measuring from 0.003 to 0.009 by 0.0003 to 0.0006 mm., some specks of pyrite 0.0043 by 0.022 mm., and large pyrite octahedra surrounded by a rim of chlorite scales, rarely a transparent scale (muscovite).

Under polarized light the parallel sections show the same carbonate rhombs, but in very much smaller number than in the fading "sea-green" slates, size 0.026 to 0.065 mm., quartz grains 0.008 to 0.043 mm., and muscovite straps from 0.015 to 0.060 mm. in length.

The reason these slates are "unfading" is manifestly because they have fewer rhombs of carbonate of iron and lime and magnesia. The sections also show why they cleave less perfectly than the "sea-green" slates.

SLATE-PENCIL SLATE.

In the unfading green slate portion of the belt, about 1½ miles north of Bomoseen and a little east of the lake, is an abandoned quarry where certain greenish slates were obtained and made into slate pencils. In Europe slate pencils have long been made by utilizing a secondary cleavage, which breaks the rock up into squarish sticks which are easily rounded. Here, however, the method was to take tile-shaped blocks of slate and carve out, first on one side, then on the other, by means of set gauges, a whole series of hemicylindrical pencils which readily broke apart into roundish pencils. A microscopic section of this rock shows essentially the same composition as the unfading green

¹In repairing roofs covered with this slate the fresh slate makes a slight contrast with the old.

slates, excepting that sections parallel to the cleavage show no carbonate whatever, but a greater abundance and larger scales of muscovite (probably elastic), some limonite (?) specks, and a cleavage perhaps not quite so good as that of the Eureka quarries. The usual quartz, sericite, chlorite, rutile needles, and lenses are present.

THE PURPLE AND VARIEGATED ROOFING SLATES.

CHEMICAL ANALYSES.

The following analyses were made by Dr. W. F. Hillebrand in the laboratory of the United States Geological Survey:

Analyses of purple and variegated roofing slates.

Constituents.	Specimens. ^a			
	G.	II.	I.	II ^b .
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
SiO ₂ (silica).....	61.63	60.96	60.24	.....
TiO ₂ (titanium dioxide).....	.68	.86	.92	.....
ZrO ₂ (zirconia).....	.....	Trace?	Trace?	.....
Al ₂ O ₃ (alumina).....	16.33	16.15	18.46	.....
Fe ₂ O ₃ (ferric oxide).....	4.10	5.16	2.56	5.28
FeO (ferrous oxide).....	2.71	2.54	5.18	2.36
MnO (manganous oxide).....	.09	.07	.07	.....
NiO (nickelous oxide).....	Trace?	Trace.	Trace.	.....
CoO (cobaltous oxide).....	Trace?	Trace.	Trace.	.....
CaO (lime).....	.50	.71	.33	.....
BaO (baryta).....	.06	.04	.03	.....
MgO (magnesia).....	2.92	3.06	2.33	.....
K ₂ O (potassa).....	5.54	5.01	4.09	.....
Na ₂ O (soda).....	1.26	1.50	1.57	.....
Li ₂ O (lithia).....	Str. tr.	Trace.	Str. tr.	.....
H ₂ O (water below 110° C.).....	.31	.17	.18	.....
H ₂ O (water above 110° C.).....	3.24	3.08	3.81	.....
P ₂ O ₅ (phosphoric oxide).....	.16	.23	.11	.....
CO ₂ (carbon dioxide).....	.41	.68	.08	.....
FeS ₂ (pyrite).....	.04	None.	.16	.....
SO ₂ (sulphuric oxide).....	Trace.	.....	.....	.....
C (carbon).....	None.	None.	None.	.....
Total.....	99.98	100.22	100.12	.....
S (total sulphur above).....	.02	.07	.087	.....
Specific gravity.....	2.8064	.....	2.8053	.....

^a G (=D. XIV, '95, 260a), purple roofing slate, McCarty quarry, east of center of Lake Saint Catherine, South Poultny, Vermont. II (=D. XV, '95, 760a), purple roofing slate, Francis & Sons quarry, nearly a mile south of Hydeville, in Castleton, Vermont. I (=D. XV, '95, 314), variegated roofing slate, from Eureka quarry, 3½ miles north of Poultny, in Poultny Township, Vermont, "unfading green" area. II^b (=D. XIV, '95, 614a), dark reddish bed a few inches thick in purple of sea-green area, west of Lake Saint Catherine; determination of iron oxides only.

^b Lower Cambrian, Horizon B, Olenellus zone.

MICROSCOPIC ANALYSIS.

The "purple" slate is a dark purplish brown. The "variegated" is like the "sea green" or "unfading green," but is irregularly patched with purplish brown. The discoloration of the purple is less marked than that of the "sea green." It effervesces more or less with cold dilute hydrochloric acid.

Sections of the purple across the cleavage seen in ordinary light show a cleavage corresponding in fineness to that of the "sea green." Numerous very minute reddish specks of hematite (Fe_2O_3) and exceptionally a hexagonal scale of the same are conspicuous. Under polarized light such sections are seen to consist of a matrix of fibrous muscovite polarizing as one mineral, with the usual quartz fragments, carbonate rhombs, chlorite scales, muscovite straps, and rarely a fragment of plagioclase feldspar and of zircon.

Sections parallel to the cleavage under ordinary light show rutile needles (TiO_2) and very minute and irregularly shaped red dots of hematite. Under polarized light the quartz fragments, carbonate rhombs, chlorite scales, and muscovite straps are brought out. The chief microscopic difference between the purple and the "sea green" seems to be the presence in the purple of the additional mineral, hematite, and the scarcity of pyrite, and the somewhat smaller number of carbonate rhombs.

The variegated slate from the Eureka quarries does not effervesce with cold dilute hydrochloric acid applied to the edges, and in the irregularity of its cleavage resembles the "unfading green" from the same quarry. Even transverse sections show the irregular distribution of the hematite dots which produce the mottled appearance. There are also specks of pyrite and large flakes of chlorite throughout.

Under polarized light quartz appears up to 0.047 and even 0.071 mm. There are lenses of quartz a millimeter long, and muscovite and chlorite scales without definite arrangement, about which the sericite matrix bends. Many muscovite and chlorite scales in other parts of the slide lie at an angle to the cleavage. A few slender prisms of tourmaline appear.

Sections parallel to the cleavage also show the irregular distribution of the hematite dots, which measure from 0.001 to 0.0035 mm. in diameter, and the usual rutile needles. There are also spherules of pyrite from 0.007 to 0.027 mm. in diameter. The same sections under polarized light bring out the quartz, the carbonate rhombs, and the chlorite and muscovite scales.

THE RED ROOFING SLATE.¹

CHEMICAL ANALYSES.

The following analyses were made in the chemical laboratory of the United States Geological Survey, the complete analyses by Dr. W. F. Hillebrand, the partial ones by Mr. George Steiger:

Constituents.	Specimens. ^a					
	J.	K.	L.	M.	K ² .	N.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
SiO ₂ (silica)	67.61	67.55	56.49	63.88	.....	.....
TiO ₂ (titanium dioxide) ..	.56	.58	.48	.47	.....	.....
Al ₂ O ₃ (alumina)	13.20	12.59	11.59	9.77	.....	.....
Fe ₂ O ₃ (ferric oxide)	5.36	5.61	3.48	3.86	7.10	1.02
FeO (ferrous oxide)	1.20	1.24	1.42	1.44	1.00	1.67
MnO (manganous oxide) ..	.10	.19	.30	.21	.....	.....
NiO (nickelous oxide)	Trace?	Trace.	Trace.	Trace.	.....	.....
CoO (cobaltous oxide)	Trace?	Trace.	Trace.	Trace.	.....	.....
CaO (lime) .....	.11	.26	5.11	3.53	.....	.....
BaO (baryta) .....	.04	.31	.06	.05	.....	.....
MgO (magnesia)	3.20	3.27	6.43	5.37	.....	.....
K ₂ O (potassa)	4.45	4.13	3.77	3.45	.....	.....
Na ₂ O (soda) .....	.67	.61	.52	.20	.....	.....
Li ₂ O (lithia)	Trace.	Trace.	Str. tr.	Str. tr.	.....	.....
H ₂ O (water below 110° C) ..	.45	.40	.37	.27	.....	.....
H ₂ O (water above 110° C) ..	2.97	3.03	2.82	2.48	.....	.....
P ₂ O ₅ (phosphoric oxide) ..	.05	.10	.09	.08	.....	.....
CO ₂ (carbon dioxide)	None.	.11	7.42	5.08	.....	.....
FeS ₂ (pyrite) .....	.03	.04	.03	Trace.	.....	.....
SO ₃ (sulphuric oxide)	Trace.	Trace.	Trace.	.....	.....	.....
C (carbon)	None.	None.	None.	None.	.....	.....
Total	100.00	100.02	100.38	100.14	.....	.....
S (total sulphur) .....	.016	.02	.016	.....	.....	.....
Specific gravity .....	.....	.....	2.7839	.....	2.8085	.....

^aJ (= D. XIV, '95, 356d), red slate, H. H. Matthews's quarry, 1 mile west of Paultney, in Hampton, Washington County, New York; K (= D. XIV, '95, 261e), red slate, Empire Red Slate Company's quarry, 1 mile north of Granville, in Granville, Washington County, New York; L (= D. XIV, '95, 397e), red slate, National Red Slate Company's quarry, 1 mile north-northwest of Raceville, in Granville, Washington County, New York; M (= D. XIV, '95, 397a), red slate, same locality as L, but near a green and purple spot; K² (= D. XIV, '95, 261b), red slate, same as K, but finer grained; N (= D. XIV, '95, 284a), purple bed in red slate at Fair Haven Red Slate Company's quarry (not worked), 2 miles north of Truthville, in East Whitehall, Washington County, New York. For presence of chromium and vanadium in these see Dr. Hillebrand's appendix in Prof. Dale's paper.

¹Ordovician (Lower Silurian), Horizon Irs (Hudson red and green slate).

MICROSCOPIC ANALYSIS.

The "red slate" is a decidedly reddish-brown, not so dark generally as the purple, and becomes still brighter on exposure. An outcrop of it, even at a distance, is a conspicuous object on account of its color. It is not infrequently speckled with minute protuberances or "eyes." Some of this slate effervesces with cold dilute hydrochloric acid.

Thin sections across the cleavage show in ordinary light much irregularity in the size of the transparent particles, and therefore of the cleavage. These particles measure from 0.015 to 0.06 by 0.006 to 0.03 mm. Multitudes of red dots (hematite, Fe_2O_3), from 0.01 down to much less than 0.001 mm., and a greater or lesser abundance of lenses, up to 0.032 by 0.15 mm., of fine granular material of a slightly bluish color. Under polarized light such sections polarize as one mineral, but not so brilliantly as cross sections of the Cambrian slates, either because the muscovite is in part obscured by the pigment of Fe_2O_3 or because there is less of it and this slate approaches a clay slate. The transparent grains prove to be partly quartz fragments, partly carbonate in rhombs or irregular plates up to 0.047 mm., rarely grains of plagioclase feldspar. There are also chlorite scales up to 0.075 by 0.036 mm., and, exceptionally, a fragment of zircon. The granular lenses under high power resolve themselves into a matrix which closely resembles in color and structure thin sections of the small beds of rhodochrosite (carbonate of manganese) heretofore referred to as occurring in these same slates.¹ This matrix consists, however, in part of cryptocrystalline quartz, and contains rhombs of carbonate and considerable muscovite. One of the slides has a lens one-half millimeter long, containing a rhomb partly of calcite and partly of chlorite.

Sections parallel to the cleavage in ordinary light, under an enlargement of 1,100 diameters and immersion, show the hematite dots in circular or irregularly oval outlines, measuring from 0.0004 to 0.009 mm., and, under polarized light, quartz grains 0.043 by 0.029 mm.; carbonate, chlorite scales, and tourmaline prisms up to 0.005 by 0.001 mm.

Associated with the red slate is generally a little purple slate, sometimes speckled, but not of commercial consequence. Under the microscope this shows the same composition as the red, excepting that there is less of the iron pigment and possibly more chlorite. Analysis N, on page 51, shows from $2\frac{1}{2}$ to over 4 per cent less Fe_2O_3 and about one-third of 1 per cent more FeO. The specks or lenses consist of cryptocrystalline quartz or rhodochrosite, and are surrounded by the meshes of sericite. Rarely a zircon fragment occurs.

¹ For analysis see p. 61.

THE BRIGHT-GREEN ROOFING SLATE.¹

The following analysis (specimen O = D. XIV, '95, 397c), by Dr. W. F. Hillebrand, is of a bright-green speckled slate from the National Red Slate Company's quarry, 1 mile north of Raceville, in Granville, Washington County, New York:

CHEMICAL AND MICROSCOPIC ANALYSIS.

Constituents.	Specimen O.	Constituents.	Specimen O.
	<i>Per cent.</i>		<i>Per cent.</i>
SiO ₂ (silica)	67.89	Na ₂ O (soda) .....	.77
TiO ₂ (titanium dioxide) ..	.49	Li ₂ O (lithia)	Trace.
Al ₂ O ₃ (alumina)	11.03	H ₂ O (water below 110° C.) ..	.38
Fe ₂ O ₃ (ferric oxide)	1.47	H ₂ O (water above 110° C.) ..	3.21
FeO (ferrous oxide)	3.81	P ₂ O ₅ (phosphoric oxide) .....	.10
MnO (manganous oxide) ..	.16	CO ₂ (carbon dioxide)	1.89
NiO (nickelous oxide)	Trace?	FeS ₂ (pyrite) .....	.04
CoO (cobaltous oxide)	Trace?	SO ₃ (sulphuric oxide)	Trace.
CaO (lime)	1.43	C (carbon)	None.
BaO (baryta) .....	.04	Total	100.08
MgO (magnesia)	4.57	S (sulphur, total) .....	.022
K ₂ O (potassa)	2.82		

Specific gravity = 2.7171.

These are generally interbedded with the red slates, and probably, in places, merge into them along the strike. The color is a light bluish green, more decidedly greenish than the Cambrian slates. The green is peculiarly bright by lamplight. The surface is also sometimes speckled. It effervesces very slightly with cold dilute hydrochloric acid. It is said not to fade readily.

Thin sections across the cleavage show a cleavage not remarkably good on account of the large size of the particles, and more inferior when the slate is speckled. The speckling is due to lenses of granular material which measure up 0.375 by 0.128 mm. There are some grains of pyrite. Under polarized light such sections show the usual polarization of the matrix as one mineral more brightly than the red slates do, quartz grains up to 0.065 mm., chlorite scales up to 0.043 mm., carbonate up to 0.056 mm. The lenses consist of cryptocrystalline quartz, with some very minute rhombs of carbonate and scales of chlorite.

Sections parallel to the cleavage under ordinary light show the lenses with more of a roundish outline, from 0.077 to 0.385 mm. in diameter, rutile needles, and dots of pyrite.

Thin sections under polarized light yield quartz fragments 0.084 by 0.056 mm., carbonate rhombs from 0.002 to 0.93 mm., chlorite scales, tourmaline prisms, zircon, actinolite (?).

¹ Ordovician (Lower Silurian), Horizon Ira (Hudson red and green slate).

THE BLACK ROOFING SLATES.¹

CHEMICAL ANALYSIS.

The following analysis (specimen P = D. XIV, '95, 305d) of black slate from the American Black Slate Company's quarry, one-fourth mile east of Benson Village, Rutland County, Vermont, was also made by Dr. W. F. Hillebrand.

Constituents.	Specimen.	
	P.	(a)
	<i>Per cent.</i>	<i>Per cent.</i>
SiO ₂ (silica)	59.70	55.880
TiO ₂ (titanium dioxide, rutile).....	.79	1.270
Al ₂ O ₃ (alumina)	16.98	21.849
Fe ₂ O ₃ (ferric oxide).....	.52	.....
FeO (ferrous oxide).....	4.88	9.033
MnO (manganous oxide).....	.16	.586
NiO (nickelous oxide).....	Trace?	.....
CoO (cobaltous oxide).....	Trace?	Trace.
CaO (lime).....	1.27	.155
BaO (baryta).....	.08	.....
MgO (magnesia).....	3.23	1.495
K ₂ O (potassa)	3.77	3.640
Na ₂ O (soda)	1.35	.460
Li ₂ O (lithia).....	Str. tr.	.....
H ₂ O (water below 110° C.).....	.30	} 3.385
H ₂ O (water above 110° C.).....	3.82	
P ₂ O ₅ (phosphoric oxide) .....	.16	.....
CO ₂ (carbon dioxide).....	1.40	.....
FeS ₂ (pyrite)	1.18	.051
SO ₃ (sulphuric oxide).....	Trace.	.022
C (carbon) .....	.46	1.794
Total	100.05	99.620
S (total sulphur included above).....	.63	.....
Specific gravity	2.7748	.....

^a This analysis is inserted for comparison. It is by Andrew S. McGrenth, Second Geological Survey Pennsylvania, Report of Progress, 1877, Vol. CCC, pp. 269, 270, 1880; Peach Bottom slates (black) from J. Humphreys & Co.'s quarry, one-half mile east of Delta, York County, Pennsylvania. The footing given is 99.800.

¹ Ordovician (Lower Silurian) or Lower Cambrian, Horizon G or D.

MICROSCOPIC ANALYSIS.

This slate is quite black. The luster is not so bright as that of the Maine slates, but similar to that of the Pennsylvania slates. It effervesces with cold dilute hydrochloric acid.

Sections across the cleavage in ordinary light show a fairly good cleavage and abundance of minute opaque spherules, which, under incident light, glisten like pyrite. They are sometimes in rows along the cleavage. There are also slate needles and transparent grains. Under polarized light the sericite matrix polarizes as one mineral; quartz fragments and carbonate in plates and lenses appear.

Sections parallel to the cleavage under ordinary light show a cloudy grayish matrix with transparent minerals, large and small black dots and blotches, and slate needles in abundance from 0.0017 to 0.0952 mm. in length. The pyrite spherules measure from 0.0017 to 0.007 mm. Under polarized light these sections show carbonate rhombs 0.0043 to 0.035 mm., quartz grains 0.013 to 0.030 mm., and muscovite scales.

MICROSCOPIC ANALYSIS OF "MILL STOCK."

There remains yet to be described those slates which are designated as "mill stock." In consequence of their less perfect cleavage they are not well adapted for roofing slates, but are sawn up for a great variety of other purposes—blackboards, billiard tables, tiles, mantles, vats, tablets, etc.

They are purple or green or red. The purple is frequently paler than that of the roofing slates and spotted with green, while the green is fully as bright and sometimes brighter than that of the "unfading-green" roofing slates. The red is the Ordovician red. No chemical analyses of these were undertaken, but the following results were obtained from microscopic analyses of specimens of purple and green from the Scotch Hill quarries, 2 miles north-northeast of Fairhaven; from the Meadow quarry, one-fourth mile east of Fairhaven; from the Lake Bomoseen Slate Company's quarry, at Cedar Point, in Castleton; and from the J. Jones quarry, 2½ miles north of Castleton village. These are all of Lower Cambrian age (Horizon B).

Sections of the green across the cleavage in ordinary light show a cleavage greatly inferior to that of the "sea-green" roofing slates, and somewhat inferior to that of the Eureka "unfading green." There is an unusual abundance of large green dichroic scales (chlorite), many of which lie at right angles to the cleavage; also large transparent angular grains, some octahedra of pyrite, and rutile needles.

Under polarized light such sections polarize as one mineral, owing to the matrix of sericite and the cleavage. The chlorite flakes measure up to 0.087 by 0.043 mm., and are interleaved with muscovite (or talc). The quartz fragments measure up to 0.060 by 0.036 mm. Muscovite scales occur in various orientations.

Sections parallel to the cleavage show under ordinary light the usual abundance of rutile needles and under polarized light the quartz grains, chlorite scales, muscovite scales, and some carbonate rhombs. The large chlorite scales are conspicuous under incident light. The purple mill stock is similar to the green, with the exception of the additional dots of hematite (Fe_2O_3).

The specific gravity of purple mill stock from Cedar Point was found to be 2.83, and of green mill stock from the J. Jones quarry 2.84, both a little higher than any of the roofing slates.

THE SPOTTED SLATES.

The spots in roofing slates have long attracted attention.¹ In this region the purple slates often have green spots of circular or oval, but frequently of irregular outline. These spots sometimes occur only along lines of bedding and correspond or pass into green "ribbons." In places, however, an entire bed of purple slate several feet thick is irregularly spotted throughout. The red slates are also often spotted. The spots are frequently circular or oval and measure from a fraction of an inch to several inches in diameter and of pale green color with or without a purple border. Some of the spots, however, have no symmetry whatever. In order, if possible, to throw some new light on this subject a few thin sections were prepared across small spots in directions parallel to and across the cleavage, and in the case of the spotted red slates chemical analyses were made by Dr. Hillebrand of the green center of the spot, of its purple rim, and of the outer red slate.

MICROSCOPIC ANALYSES.

An elliptical green spot, 1 by $\frac{3}{4}$ inch, in purple Cambrian slate from the Lake Bomoseen Slate Company's quarry, at Cedar Point, Castleton, Vermont, in a section cut parallel to cleavage, shows, in the green part, muscovite scales lying in all directions, large chlorite scales, quartz fragments, carbonate rhombs, and a few irregular spherules of pyrite. In the center is some opaque noncalcareous matter partly surrounded by an aggregation of spherules of pyrite in a cloud of rutile needles. There are also cracks filled with secondary sericite. In the surrounding purple the same elements recur, but the pyrite is much more abundant, measuring up to 0.021 mm. There are also many dots of Fe_2O_3 from less than 0.003 to 0.009 mm. and rutile needles up to 0.012 mm. in length.

¹ Comparative view of the cleavage of crystals and slate rocks, by John Tyndall: *Phil. Mag.*, vol. 12, July, 1856. On the disposition of iron in variegated strata, by George Maw: *Quart. Jour. Geol. Soc.*, Vol. XXIV, p. 379; also on variegated Cambrian slates, by the same author: *Pl. XIV*, figs. 29, 31, 32, London, 1868. Les schistes de Fumay, by Gosselet: *Ann. Soc. Géol. du Nord*, Vol. X, pp. 63-86, Lille, 1884; same author, *L'Ardenne*, 1888, p. 35. Text-book of Geology, by Archibald Geikie, 3d ed., p. 343, (2) 1893. *Lehrbuch der Petrographie*, by F. Zirkel, 2d ed., Vol. III, pp. 296-297, 1894.

An elliptical green spot, 3 inches long, with a purple rim, in Ordovician red slate from the National Red Slate Company's quarry northwest of Raceville (Specimen D. XIV, '95, 397a), when cut transversely to the cleavage, measures a half inch in thickness and shows a black streak 1 inch long in the center. The central streak consists of strings of minute irregular lenses of cryptocrystalline quartz and possibly carbonate of manganese (rhodocrosite) containing spherules of pyrite. The green part consists of a mass of fibers of muscovite, which polarize as one mineral, with much carbonate and many lenses, and also quartz grains. In the purple rim there is a decrease of carbonate, and the hematite fragments begin to appear and become still more abundant in the surrounding red slate itself.

A green spot in Ordovician red slate (D. XIV, '95, 201c) from the Empire Red Slate Company's quarry, a mile north of Granville, cut parallel to the cleavage, shows slate needles (TiO_2) up to 0.043 mm. long, carbonate rhombs up to 0.030 mm., chlorite scales up to 0.030 mm., angular quartz grains up to 0.039 mm., and prisms of tourmaline up to 0.021 by 0.002 mm. The surrounding red slate, that of Analysis K, page 51, has been described in the general description on page 52.

Another spot, almost circular, 0.44 inch in diameter, from a piece of red slate (D. XIV, '95, 2011) from the same quarry, cut parallel to the cleavage, shows a central dot 0.03 inch in diameter, consisting mainly of carbonate and of a dense brown material. About this is a zone about 0.1 inch wide, of elliptical shape, of carbonate, with some fibrous quartz along the margin. Then comes a zone 0.08 inch wide, of green slaty material, containing angular quartz grains, muscovite scales, rutile needles, nodules of pyrite, and thinly disseminated areas and rhombs of carbonate; then a very narrow zone made up entirely of carbonate and pyrite. Outside of this, another green slate zone 0.08 inch wide, like the first, but with very little carbonate. The angular quartz grains measure up to 0.030 mm. There are also slender tourmaline prisms. Outside of all comes the red slate, full of Fe_2O_3 pigment. Chlorite was not detected in the green zones, but it may be present in minute scales.

CHEMICAL ANALYSES OF SPOTS IN RED SLATE.

The specimen (Q, R) analyzed by Dr. Hillebrand came from the same quarry as the large spot described on page 58. It was a green spot with purple rim, in red slate. The analysis of the red slate M, on page 51, is repeated for comparison.

Chemical analyses of spotted red slate.

Constituents.	Specimens, ^a		
	M.	Q.	R.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
SiO ₂ (silica)	63.88	64.59	65.44
TiO ₂ (titanium dioxide, rutile) .....	.47	.51	.52
Al ₂ O ₃ (alumina)	9.77	10.23	9.38
Fe ₂ O ₃ (ferric oxide)	3.86	1.79	1.09
FeO (ferrous oxide)	1.44	1.19	1.06
MnO (manganous oxide) .....	.21	.26	.32
NiO (nickelous oxide)	Trace.	Trace.	Trace.
CoO (cobaltous oxide)	Trace.	Trace.	Trace.
CaO (lime)	3.53	4.07	4.53
BaO (baryta) .....	.05	.05	.06
MgO (magnesia)	5.37	5.12	4.92
K ₂ O (potassa)	3.45	3.70	3.57
Na ₂ O (soda) .....	.20	.23	.22
Li ₂ O (lithia)	Str. tr.	Str. tr.	Str. tr.
H ₂ O (water below 110° C.) .....	.27	.28	.25
H ₂ O (water above 110° C.)	2.48	2.29	2.10
P ₂ O ₅ (phosphoric oxide) .....	.08	.08	.08
CO ₂ (carbon dioxide)	5.08	5.84	6.55
FeS ₂ (pyrite)	Trace.	Trace.	.04
Total	100.14	100.23	100.13

^a M (=D. XIV, '95, 397a), red slate, 1 mile north-northwest of Raceville, in Granville, Washington, County, New York, about a spot; Q, purple rim of the spot; R, green portion of the spot.

Dr. Hillebrand adds this observation:

Calculation shows that with no CO₂ there would be only enough CaO for the P₂O₅, and, further, that the result would be no MnO. How much FeO, if any, exists as carbonate is not indicated. If, after allowing for apatite, for MnCO₃, and CaCO₃, the remainder of the CO₂ is charged to MgO, we find the proportions shown in the columns below.

	M.	Q.	R.
CaO ₃	6.14	7.11	7.93
MgCO ₃ (in part FeCO ₃)	4.22	4.77	5.36
MnCO ₃ .....	.38	.47	.57

DISCUSSION OF THE SPOTS.

From Dr. Hillebrand's analyses it would appear that there is a decrease of the carbonates of lime and manganese and magnesia and of silica and rutile from the center of the spot outward and an increase of Fe_2O_3 in the same direction.

The main results of the microscopic and chemical analyses agree even as to the relative amount of pyrite. The difference in color from the green to purple to red is manifestly due to the differences in the amount of hematite. Pyrite, rutile, carbonate, and tourmaline are more abundant within the spots than without them.

The green fossil impressions in purple slate may throw some light on the origin of these spots. In this case the effect of organic matter, whether the carbonaceous matter of the lining of an annelid boring or from a marine alga, has been to diminish the quantity of Fe_2O_3 in the slate, and possibly to increase the amount of chlorite.¹ Gosselet regards the spots as the result of the reduction of the hematite (Fe_2O_3) by decaying organisms to the ferrous oxide (FeO) and its removal as an organic salt or as a carbonate. He observes that the green spots in purple tiles wear less readily than the rest of the tile, because they contain more quartz, and this SiO_2 he attributes to infiltration.²

In the spots examined from the New York and Vermont slates the marked decrease of Fe_2O_3 is accompanied by a marked increase of carbonate of lime, iron, and manganese,³ and of SiO_2 , also by a slight increase, in some of the thin sections at least, of FeS_2 . Carbonates are also characteristic of the spots in some European slates.³ The increase of the carbonates may be directly connected with the production of CO_2 by decaying organisms and the consequent decrease of the Fe_2O_3 . Not impossibly the organism may have had a calcareous exoskeleton which was dissolved and then redeposited as crystalline CaCO_3 . The infiltration of SiO_2 and the formation of chalcidony may be purely secondary, and likewise the deposit of FeS_2 , or there may have been some precipitation of FeS_2 about the decaying organism, as seems to have been the case in some fossils. At any rate, the rim of intermediate composition would be the zone in which chemical reaction was less effective.

In view of all these facts and indications, the spots may be safely regarded as probably produced by chemical changes in the sediments consequent upon the decay of organisms.

If this be the correct view, the green ribbons, which traverse both purple and red slate, would correspond to small deposits of decomposing organic material that effected similar changes in the Fe_2O_3 of the

¹ See Tyndall, Maw, Gosselet, Geikie, and Zirkel, as indicated by titles given in footnote on p. 56.

² Maw (loc. cit.) had analyses made of dark greenish ribbons in the Welsh blue slates, and found that the ribbons contained 6 per cent more SiO_2 , 7 per cent more Al_2O_3 , $4\frac{1}{2}$ per cent more MgO (= 7 times as much), but 4 per cent less Fe_2O_3 , 1 per cent less FeO , and $8\frac{1}{2}$ per cent less K_2O than the adjacent blue beds. Under the microscope the green ribbons showed more feldspar and chlorite. He attributes these differences to change in sedimentation.

³ See Zirkel, loc. cit.

argillaceous sediments. Where a bed of quartzite forms the center of such a ribbon quartzose sedimentation must have taken place also, and possibly may have been the very condition which proved favorable to marine life.

MINERALS ASSOCIATED WITH THE SLATES.

As the minerals of visible size associated with the slates throw light on the nature and origin of the microscopic constituents of the slate itself, they will now be described.

Quartz is the most common accessory mineral. It is usually segregated in the veins already described, but occurs also as an infiltrated cement between the quartz grains in the beds of quartzite or in veins traversing the quartzite. In both of these modes it is crystallized whenever cavities admit of it.

Next in abundance is *calcite*, occurring also in veins with or without quartz, or as delicate films on joint planes, or as a sediment in the beds of quartzite. The quartzite beds sometimes contain minute rhombs which effervesce readily with hydrochloric acid and weather a limonite brown, and are therefore probably a double carbonate of iron and lime.

Squarish or oval concretions an inch by three-fourths of an inch and one-half inch thick, consisting of radiating crystalline lamellæ of *barite* with the intervening spaces filled with slate and calcite and with many minute cubes of pyrite round about, occur in the Cambrian green slates of Middle Granville. Barite also occurs with calcite in crystalline films on joint planes in both Cambrian and Ordovician slates.

Chlorite is common in quartz veins or almost alone makes up small veins, or coats slickensided joint or bedding planes.

Pyrite occurs in cubes up to one-fourth inch across or in botryoidal concretions, coated with fibrous quartz (chalcedony) or with calcite or, more rarely, chlorite. This coating of chalcedony is often confined to some of the sides, filling a space produced by motion or compression, as described by Renard. Pyrite may collect in the vicinity of calcareous and quartzose veins or beds or form dendritic crystallizations on cleavage planes or minute cubes on joint faces. That this mineral is pyrite and not marcasite is shown by its not decomposing readily after long exposure on the slate dumps.¹

¹ See in this connection Alexis A. Julien, On the variation of decomposition in the iron pyrites; its cause, and its relation to density. *Annals N. Y. Acad. Sci.*, Vol. III, pp. 365-403; Vol. IV, pp. 125-221 and Pls. VIII, IX; 1886, 1887.

Beds of *carbonate of manganese* (rhodochrosite) a half inch thick, with calcite and quartz, occur in the red Ordovician slates. An analysis of this, made by Mr. George Steiger, yielded the following:

Analysis of rhodochrosite.

Constituents.	Per cent.
Al ₂ O ₃	0.68
Fe ₂ O ₃.....	.14
FeO.....	1.13
MnO.....	32.22
NiO and CoO.....	.10
CaO.....	3.81
MgO.....	2.61
CO ₂	25.06
Insoluble matter, including all silica from dissolved silicates.....	32.75
Total.....	98.50

Under the microscope thin sections of this bed show, under polarized light, a fine-grained bluish-brown matrix identical in color and texture with that of the small lenses in the red slate and with some of the lenses in the green slate; also large areas of calcite and some quartz.

Rarely a little *galenite* occurs in the quartz veins of both Cambrian and Ordovician slates. It will be observed that all these minerals, excepting the last, have already been mentioned as occurring in the slates, as shown either by the chemical or microscopic analyses.

SLATES FROM OTHER REGIONS.

It is not within the scope of this report to make a comparative study of slates, either for economic or scientific purposes, but a selection from the published analyses of various slates is here given, and the results of microscopic analyses by the writer of a few sections of slate from Wales, Pennsylvania, and Maine are added, and a few comparisons drawn.

Very few complete analyses of roofing slates are given in scientific literature. Several of the rarer elements are usually omitted in the determinations. FeO and Fe₂O₃ are not distinguished, nor CaO and CO₂, so that several of the percentages are more or less misleading.

The following, however, are the most reliable and complete analyses readily accessible:

Selected analyses of slates from other regions.

Constituents.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
SiO ₂ (silica)	58.39	61.57	65.63	61.43	67.56	59.35	55.880	55.06	60.68
TiO ₂ (titanium dioxide) ..	.23	1.31	.94	.73	.....	1.60	1.270	.....	.59
Al ₂ O ₃ (alumina)	21.89	19.22	20.20	19.10	12.23	13.56	21.849	22.55	21.20
Fe ₂ O ₃ (ferric oxide)	7.05	6.63	2.72	4.81	2.87	1.10	.....	1.97	5.68
FeO (ferrous oxide)	2.57	1.20	.85	3.12	6.90	4.75	9.033	5.96	.46
CaO (lime) .....	.39	.22	.19	.31	.27	5.20	.155	1.30	1.71
MgO (magnesia)	1.09	2.00	1.54	2.29	3.03	3.60	1.495	2.92	.88
K ₂ O (potassa)	2.45	3.63	3.81	3.24	1.76	1.77	3.640	3.82	3.64
Na ₂ O (soda)	1.18	.93	.71	.83	1.28	1.48	.460	2.17	2.00
CO ₂ (carbon dioxide) .....	.....	.....	.....	.....	.....	4.45	.....	.....	.....
C (carbon) .....	.....	.....	.....	.....	3.11	.....	1.794	.....	.07
MnO (manganous oxide) ..	.....	.....	.....	.....	.....	.....	.....	.....	.....
P ₂ O ₅ (phosphoric oxide) ..	.....	.....	.....	.....	.10	.31	.608	.....	.10
SO ₃ (sulphuric oxide) .....	.....	.....	.....	.....	.....	.....	.....	.....	.....
H ₂ O	4.61	3.25	3.17	3.52	1.00	3.41	3.385	4.35	2.88
FeS ₂ .....	.....	.....	.....	.....	.....	.....	.051	.....	.....
Total	99.76	99.96	99.76	99.38	100.20	99.98	99.629	100.10	100.04
Specific gravity	2.81	.....	.....	.....	.....	.....	.....	2.78	.....

I. Gray roofing slate, best quality, Delabole, Camelford, Cornwall; two analyses by J. A. Phillips, London, Edinb. & Dublin Phil. Mag., 4th ser., No. 27, pp. 95-96, Feb., 1871.

II. Purple roofing slate, Fumay, Ardennes, northwest France; by A. Renard, Recherches sur la composition et la structure des phyllades ardennais; Bull. Mus. Roy. d'Hist. Nat. de Belgique, Vol. I, p. 239, 1882.

III. Green roofing slate beds from purple, Fumay, Ardennes, as above.

IV. Blue-gray roofing slate, La Richolle quarry, Rilmogne, Ardennes, northwest France; by Klement, pub. by A. Renard, op. cit. supra, p. 233.

V. Roofing slate (probably black, Devonian), Westphalia; by H. von Dechen; Roth, Allgem. und chem. Geol., II, pp. 586, 587, 1884. (107.)

VI. Roofing slate (color not given, Devonian), Frankenberg, near Goslar, in Prussia; by A. von Groddeck; Jahrb. pr. Geol. Landesanst., 1885-86; quoted in Roth, Allgemeine chem. Geol., II, pp. 586, 587.

VII. Black roofing slates ("Peach Bottom") from J. Humphreys Co.'s quarry, half a mile east of Delta, York County, Pennsylvania; by Andrew S. McCreath, in 2d Geol. Surv. Pa., Report of Progress, 1877, Vol. CCC, pp. 269, 279, 1880. The footing given in original is 99.800. (Repeated from p. 54.)

VIII. Bluish roofing slate of Carboniferous age, Mohradorf, near Wigstadt, Austrian Silesia; by Nikolic, in Tschermaks, Min. Mitth., 1871, p. 297; quoted by Roth, op. cit. supra, pp. 588-589.

IX. Blue slate, Glyn quarries, Llanberis, Wales; analysis made at Museum of Practical Geology, London, for George Maw, Geol. Mag. London, 1898, Vol. V, p. 128.

MICROSCOPIC ANALYSES OF SLATES FROM OTHER REGIONS.

Dark purple (so-called "red") roofing slate from Penrhyn, Wales.—Does not effervesce with cold dilute hydrochloric acid. A section across the cleavage in ordinary light shows an irregular orientation of particles and not a little irregularity in their size. The cleavage is inferior to that of the Vermont "mill stock" slate, although the irregularity in size of particles is no greater. Under polarized light this section does not polarize as one mineral, or polarizes very faintly so. It is a clay slate. The minerals are muscovite (sericite), quartz up to 0.037 mm.,

chlorite up to 0.093 mm., pyrite, hematite. A section parallel to cleavage shows muscovite scales, quartz grains up to 0.187 mm., chlorite scales from 0.1 up to 0.24 mm., hematite dots from 0.0005 to 0.017 mm.; rutile needles not very plentiful. The absence of carbonate is noticeable. Many of the dots which appear black in center of section are reddish under incident light and translucent at edge of section, and are therefore hematite.

Black roofing slate from Festiniog, Wales.—Does not effervesce with cold dilute hydrochloric acid. A section across the cleavage shows a much better cleavage and fewer coarse particles than the Penrhyn section. It polarizes as one mineral under polarized light, yet the orientation of the particles is not so regular as in the "sea-green" of Vermont and New York. The constituent minerals are muscovite (sericite), quartz fragments up to 0.065 mm., chlorite scales up to 0.09 mm., plagioclase feldspar up to 0.027 mm. Sections parallel to the cleavage show the entire absence of carbonate, abundance of rutile needles, and the other minerals just named.

The specific gravity of this slate, tested by the same methods as the American roofing slates, was found to be 2.751.

Purple (so-called "red") roofing slate from Cilgwyn Nantlle, in Wales.—Effervesces with cold dilute hydrochloric acid. The transverse section shows a cleavage about as good as that of the Festiniog slate. The parallel section shows much more and more brilliant Fe_2O_3 than that of the Penrhyn slate. The hematite dots measure from 0.0005 up to 0.01 mm. There are quartz grains, plagioclase grains, chlorite scales up to 0.047 mm., and carbonates up to 0.035 mm.

Black roofing slate ("Lehigh"), Pennsylvania.—The specimen, after being exposed for several years, had become discolored to a brownish gray on the surface. It effervesces with cold dilute hydrochloric acid applied to the unweathered edge. Sections across the cleavage show a fair cleavage. The matrix polarizes as one mineral, but not very brilliantly, owing probably to the abundance of carbonate. A piece of the weathered surface attached to a slide and the other side ground down, as was done in the case of the "sea-green" slates (p. 46), shows the surface covered with carbonate rhombs more or less completely altered to limonite, showing that the cause of the discoloration is the same as in the "sea-green" slates of eastern New York and western Vermont. Ordinary parallel sections show quartz grains up to 0.056 mm., chlorite scales up to 0.205 mm., carbonate rhombs up to 0.056 mm., spherules of pyrite from 0.002 to 0.019 mm., needles of rutile and carbonaceous particles.

Black roofing slate from quarry of the Bangor Slate Company, Easton, Pennsylvania.—This effervesces on the edges with cold dilute hydrochloric acid. The constituents, arranged in the order of their relative abundance, are: Matrix of muscovite (sericite), carbonate in rhombs from 0.009 to 0.065 mm., and also in irregular plates (these rhombs sometimes have an opaque spherule as a nucleus), then quartz fragments up to 0.075 mm., pyrite and rutile, and black specks, probably carbonaceous; lastly, chlorite up to 0.075 mm.

Black roofing slate from the Brownville and Monson quarries, Piscataquis County, Maine.—This has a lustrous surface, does not discolor on exposure, does not effervesce with cold dilute hydrochloric acid. Sections at right angles to the cleavage polarize brilliantly as one mineral and show an unusual fineness in the particles, but there are a few lenses of pyrite measuring nearly 0.01 inch, and more numerous and pretty regularly disseminated black tabular crystals measuring 0.086 by 0.004 mm., with their long axes in the cleavage foliation. As a magnet applied to the powdered slate attracts these crystals, they are magnetite (FeOFe_2O_3), probably distorted octahedra. The quartz grains in transverse sections measure up to 0.043 by 0.013 mm. Sections parallel to the cleavage show magnetite octahedral faces up to 0.10 mm., pyrite, biotite scales up to 0.093 and even 0.12 mm. quartz grains, hemimorphic prisms of tourmaline, chlorite rarely, few, if any, rutile needles, no carbonate whatever. Some secondary fibrous quartz (chalcedony) surrounds the magnetite plates and the biotite scales.

The absence of carbonate and the consequent permanence of color, the very micaceous matrix and regular cleavage make this a very superior slate. It is a true phyllite.¹

SUMMARY OF CHEMICAL COMPOSITION OF THE SLATES.

By taking the average of the analyses, wherever several were made of one kind of slate, and throwing together the rarer elements and the water below 110°C . we arrive at the following as the general chemical composition of the roofing slates of this region:

Analyses of roofing slates of eastern New York and western Vermont.

Constituents.	Sea green. (3) ^a	Unfading green. (2)	Bright green. (1)	Vari- gated (Eure- ka). (1)	Purple. (2)	Red. (4)	Black. (1)	General average.
	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per cent.</i>
SiO_2 (silica).....	63.33	59.37	67.89	60.24	61.29	63.89	59.70	62.24
TiO_2 (titanium dioxide).....	.73	1.00	.49	.92	.77	.52	.79	.87
Al_2O_3 (alumina).....	14.86	18.51	11.03	18.46	16.24	11.80	16.98	15.41
Fe_2O_3 (ferrie oxide).....	1.12	1.18	1.47	2.56	4.43	4.56	.52	2.29
FeO (ferrous oxide).....	4.93	6.00	3.81	5.18	2.62	1.33	4.88	4.21
CaO (lime).....	1.20	.49	1.43	.33	.60	2.25	1.27	1.08
MgO (magnesia).....	2.98	2.36	4.57	2.33	2.99	4.57	3.23	3.14
K_2O (potassa).....	4.06	3.78	2.82	4.00	5.27	3.95	3.77	3.96
Na_2O (soda).....	1.22	1.71	.77	1.57	3.81	.50	1.35	1.21
CO_2 (carbon dioxide).....	1.41	.30	1.89	.68	.54	3.15	1.40	1.25
FeS_2 (pyrite).....	.11	.14	.04	.10	.04	.02	1.18	.24
H_2O (water above 110°C .).....	3.37	4.01	3.21	3.81	3.16	2.82	3.82	3.47
C (carbon).....	Trace.						.46	0 or .46
Sundry and water below 110°C}.....	.62	.51	.66	.39	.56	.77	.70	.62
Total.....	100.01	100.05	100.08	100.12	100.09	100.13	100.05	
Specific gravity ^b	2.776	2.795	2.717	2.805	2.806	2.796	2.774	2.783

^a Figures in parentheses indicate the number of analyses averaged.

^b Hull (op. cit.) gives the specific gravity of the Welsh slates as ranging from 170 to 180 pounds per cubic foot—i. e., 2.65 to 2.88. Festiniog, black, proves to be 2.751 (see p. 63). Analyses I and VIII, on p. 62, give 2.81 and 2.78 for a Cornish and an Austrian slate. Bayley (op. cit.) gives 2.851 for the Monson (Maine) slates.

¹ See a description of the microscopic characters of the Maine slates, by W. S. Bayley, in Bull. U. S. Geol. Surv., No. 150, pp. 311-313, which reached the author of this paper after his manuscript was completed. Professor Bayley gives a general analysis of this slate by L. M. Norton, showing .52 of CaO .

REMARKS ON THE ANALYSES.

If analysis K₂ of red slate on p. 51 be included with the four others, the per cent of Fe₂O₃ in the red slates would range from 3.48 to 7.10 per cent, and average 5.08. Comparing, then, the amount of Fe₂O₃ in the several slates we shall find that it steadily increases from the variegated to the purple and to the red, as the microscopic sections show.

On the other hand, there is a decrease of FeO in passing from the unfading green to the variegated, sea green, bright green, purple, and red. This decrease corresponds to and is probably consequent on the decrease of chlorite, a hydrous silicate of MgO and FeO.

There is more lime (CaO) and carbon dioxide (CO₂) in the red than in any of the other slates. This CO₂ occurs in part as calcite or dolomite, but also as rhodochrosite (carbonate of manganese), as shown by the analysis of the small bed (p. 62), and the close resemblance thereto of the lenses under the microscope. There is less CaO and CO₂ in the unfading green and in the variegated analyzed than in any of the slates.

There is less pyrite (FeS₂) in the red, and most in the black.

Dr. Hillebrand finds the following amounts of NH₃ in the slates analyzed: Black (specimen 305d), 0.04; sea green (specimen 225f), 0.025, and (specimen 256e), 0.008; unfading green (645a), 0.035; purple (760a), 0.0075; red (specimen 358d), 0.005; bright green (specimen 397c), 0.015. Whether this ammonia occurs as a nitride of some metal or is of organic origin could not be determined. Traces of chlorine were found when looked for; boron was not tested for. Vanadium and chromium are probably present, in all the red slates at least.

SUMMARY OF MINERAL COMPOSITION OF THE SLATES.

In the following brief descriptions both the chemical and microscopic analyses have, to a large extent, been utilized. Besides the minerals named some kaolin (hydrous silicate of alumina) is possibly also present in all the slates.

Sea green.—Largely muscovite (potash mica), quartz, chlorite, carbonate (dolomite with siderite), pyrite, with very little lime-soda feldspar, still less zircon, rutile, cryptocrystalline quartz lenses.

Unfading green.—The same as above, but much less carbonate; more pyrite and chlorite.

Bright green.—Similar to sea green, but less carbonate; more quartz lenses and chlorite, little pyrite, tourmaline, zircon.

Variegated (Eureka).—Like the unfading green, but with irregular areas over which hematite (Fe₂O₃) is thickly disseminated.

Purple.—Like the sea green, but with less carbonate, less FeS₂, and more thickly and evenly disseminated Fe₂O₃ than in the variegated.

Red.—Not so largely muscovite (potash mica), very thickly disseminated Fe_2O_3 . More carbonate, but less FeCO_3 and less FeS_2 than in any of the preceding. Quartz, carbonate of manganese, chlorite, very little plagioclase, feldspar, zircon, little rutile, tourmaline.

Black.—Matrix like the other slates of potash mica. Carbonates about as abundant as in sea green, quartz, less Fe_2O_3 and more FeS_2 than in any of the others. Rutile, coal, or graphite.

Mill-stock purple and green.—Like the unfading green and the purple, but with more chlorite in the green.

DIFFICULTIES IN SLATE QUARRYING.

The difficulties in all slate quarrying are numerous, and particularly so in this region. In the first place, the conditions of sedimentation and pressure here have varied so that a series of slate beds does not preserve its character for any great distance. Differences in composition, in hardness and softness, or in cleavage may occur unexpectedly along the strike. In the next place, the folding is so close that it is not easy to ascertain where a bed ought to recur on the east or the west. Then the stresses to which the slate mass has been subjected have been so various that irregular fissures, resulting in as irregular veins of quartz, occur at the most unexpected points.

The east-and-west jointing is sometimes so abundant as to cut up the slate into blocks of too small a size to quarry. Masses so cleft are called "posts." "Hogbacks" may also appear unexpectedly, or faults, or dikes, not to mention "false cleavage" (slip-cleavage) or lenticular beds of quartzite. The amount of overlying gravel or of weathered or shattered rock ("top rock") to be removed and the proportion of waste to product are also vital matters.¹ Besides these are the questions as to the drainage of the quarry, as to a convenient place for the "dumps," and as to the means of transporting the product. The cost of slate at some of the quarries is increased by the necessity of removing the dumps of former workings, which, for want of capital, were placed close to the quarry and on good slate. Sometimes the only way to remove these dumps is to throw the material into the quarry and hoist it up again. Several of these difficulties could be set aside by a more generous use of common sense or capital. Others, however, are not so easily disposed of; but even these may be somewhat diminished by understanding their nature and origin, and by the application of a few simple geological principles not infrequently neglected by quarrymen. The following suggestions may be of service in this way.

¹ Davies states that this ranges from 5 to 28 per cent, 8 per cent being considered a fair proportion. Watrin, referring to the Ardennes slate, gives the total waste as from 70 to 75 per cent in weight, of which from 20 to 25 occurs in quarrying and 50 in splitting and trimming.

BEDDING AND CLEAVAGE, HOW DISTINGUISHED.

Wherever the slates are traversed by "ribbons," gray in the green slates, or green in the purple and red, or marked changes in color occur and persist through a thickness of several feet, or wherever strips of quartzite or limestone occur at intervals and continue longitudinally for several hundred feet, quarrymen of any experience know that they have to do with beds, and that the quality of the slate of any one bed may be expected to continue along that bed unless some change should occur in the character of the cleavage. The quality of the slate is primarily dependent upon the character of the sediment. This changes less frequently in horizontal than in vertical directions. The changes in the character of the materials brought into the sea and deposited at one time throughout a moderately large area were fewer than between those brought in at different times at any one spot. Cleavage, being the result of a later compression, may traverse sediments of slightly different compositions with little change in direction, but will be very much affected by great changes in the material or the grain of the sediment. The prime factor is, then, the bed, the second one the cleavage.

In the southern part of the slate belt, as between West Pawlet and Poultney, where beds of quartzite or limestone are few and inconspicuous and the difference of color is slight, the distinction between bedding and cleavage is not so easily made. Quarrymen and prospectors sometimes regard them as identical when they differ. Where the strikes of the bedding and cleavage are divergent, if that of the cleavage be mistaken for that of the bedding a new opening may easily be made at the wrong point and the looked-for bed may be missed. (See fig. 1.) In such places the readiest means of distinguishing cleavage and bedding are:

- (1) The fossil impressions (trails or algae, sometimes called "wavers") are always on a bed surface.
- (2) Minute plicated beds of calcite and quartz indicate bedding.
- (3) A microscopic section transverse to the cleavage, if other means fail, may indicate the amount of divergence between the bedding and the cleavage.

In some places, however, bedding and cleavage are identical in both strike and dip.

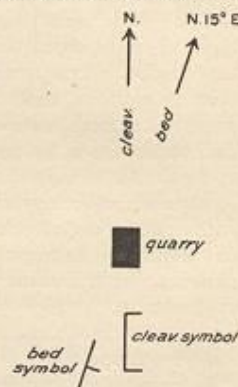


FIG. 1.—Diagram illustrating divergence in strike of slate bedding and cleavage.

"FLINTS"—THEIR NATURE AND CAUSE.

Beds of quartzite, often calcareous, micaceous, pyritiferous, should never be confounded with veins of quartz. They are both indiscriminately designated by the quarrymen as "flints." The former are sediments, mainly of quartz sands, and, although varying considerably in thickness, are generally more persistent than the veins which, as has been already shown, are chemical infiltrations into fractures produced at a much later time in consequence of various stresses. Ordinarily the quartzite has a more granular and less glassy surface than the vein quartz. A microscopic section under polarized light will almost always show the difference when ordinary means fail. The importance in not confounding the quartzite beds and the quartz veins lies in this—that while the quartzite beds indicate the direction and thickness of adjacent beds of slate, and thus prove helpful, the quartz veins constitute perhaps the most fortuitous and pernicious element in slate quarrying in this region. The strains which the slate masses have suffered have been so various, that it is almost impossible to foretell the probable presence, course, extent, or thickness of a quartz vein. A few things should, however, be noted. While the fractures which occasioned the veins are to be looked upon somewhat as accidental, they are the result of stresses affecting large areas or of the complex interactions of pressure in a few definite directions. The course of a vein which is tapering out should be taken with a compass, and another should be somewhat expected in the same line or in directions parallel to it, or at right angles to it.

RELATIONS OF JOINTS, DIKES, AND HOGBACKS.

In proximity to a dike joints may be expected parallel to the sides of the dike and in large number, so as to form "posts." The more frequent courses of the dikes within the slate belts are, as shown by the general map, N. 25° to 40° E. and N. 50° to 70° W., more rarely east and west.

Certain systems of joints, the diagonal ones, N. 30° to 40° E. and N. 45° to 50° W., and the dip joints, N. 70° W., therefore correspond to the usual courses of the dikes, and where such joints occur in any frequency dikes should be anticipated. The observed courses of the "hogbacks" (shear zones) are N. 37° to 55° E., and also, but less frequently, N. 55° W., and north, also east and west (see pp. 213, 288). As these break up the cleavage, they must be due to a movement more recent than the pressure which induced the cleavage.

From the similarity of the courses of the diagonal joints and many of the dikes, and also of many of the hogbacks, there would seem to be a close relationship in their origin. They may all have been produced by the same stress at the same time—in some cases the strain resulting in a hogback, in others in a diagonal joint—and these joints, when very deep, may have given rise to dikes. The practical applica-

tion of this is that the possibility of such a relationship should lead the quarryman, whenever he finds diagonal jointing, to suspect the proximity of hogbacks and dikes with a similar course, and so with either a hogback or a diagonal dike, and this suspicion may sometimes save expenditure of time and labor.

THE USE OF A GEOLOGICAL MAP AND COMPASS IN PROSPECTING
FOR SLATE.

Both the general map and the quarry maps are designed to be of practical utility. The coloring shows where the Cambrian green and purple and the Ordovician red slates may be looked for or not looked for. The general map, if carefully studied, will show where the continuation of certain slate belts may be expected. The dovetailing of the Cambrian and Ordovician areas, as has been explained, represents to a certain extent structural relations and not mere "accidents" of erosion. Thus, the Jamesville Cambrian belt is closely related to the Cambrian belt which lies west of South Granville.

On the quarry maps the course of bedding and cleavage has been shown at several quarries by special symbols. The scale of these maps is sufficiently large to admit the entry of many more quarries and symbols. By using a small geological compass to determine the strike of any bed of good slate at any of the located quarries, and transferring it to the quarry map by means of a protractor, the probable direction of the recurrence of the bed can be ascertained, and so with joints, hogbacks, or dikes. Such a compass should be provided with sights, spirit levels, movable ring to set off magnetic variation, and have a clinometer attachment to indicate angle of dip.

Where, as at West Pawlet, the slate is closely folded, a succession of repetitions of the same series of beds may be looked for in an east and west direction at varying intervals. The possibility of the pitching of the axis of a fold in a northerly or southerly direction should be looked out for. In such cases older or newer beds are traversed in following the direction of the pitch. Where an Ordovician belt abruptly terminates a Cambrian one on the north or south, the Cambrian one must ordinarily be supposed to plunge under the Ordovician one.

From the relations already explained, quarrymen need not be surprised, here and there as the excavation proceeds, to come upon the Ordovician red and bright-green slates at the bottom of a sea-green or unfading green quarry, or to come upon these Cambrian slates at the bottom of a red slate quarry.

Quarrymen are very skilled in detecting the presence of good slate from the peculiar appearance of the weathered edge surface, and that skill appears to have been their only guide in prospecting in this region. It would be well if this skill were reinforced by the use of the following method in exploration:

First. Make reference to a geological map for the areas in which the various slates may occur.

Second. Determine on quarry map or general map the good slate beds already exploited.

Third. Make compass determination of the strike of such beds.

Fourth. Explore along that strike.

Fifth. Explore at right angles to that strike to see if the series is repeated by folding.

Sixth. Trench at promising localities across the strike to expose as large a series as possible.

Seventh. When surface indications are favorable, make an opening large enough to determine angle of dip of both bed and cleavage and to obtain specimens sufficient for tests.

Eighth. Bore with diamond or steel-shot drill at 45° to cleavage dip so that the core will split up into elliptical pieces sufficiently larger than diameter of core to be conveniently tested.

Ninth. Measure thickness at right angles to bedding planes on the core.

METHODS OF TESTING SLATE.

Methods of testing the elasticity, absorption, fissility, and resistance of roofing slates have been in use for many years, and many more or less complete chemical analyses of slate have been published. In recent years, however, more exact methods of reaching these results have been devised. All such methods have here been brought together. If parts of one specimen, fairly representing the average quality of the product of any quarry or prospect, or if parts of each of a series of specimens, fairly representing all the different varieties and qualities there obtained, were to be subjected respectively to the tests described, such a slate or slates may be said to have been for all economic purposes exhaustively investigated. Several of these tests are of so simple a character as to be very easily applied. This list of methods is largely compiled from Böttinger, Fresenius, Hutchins, Jannetaz, Merriman, Reverdin and De la Harpe, Sorby, Umlauf, and J. F. Williams.¹ Although they all offer valuable suggestions, the most useful papers on the subject are those of Fresenius, Umlauf, and Merriman.

Sonorousness.—One of the first and most time-honored tests of roofing slate is to suspend a good-sized piece of the usual thickness and tap it with some hard object. If it possesses the molecular structure of a slate it will yield what might be termed a semimetallic or semivitreous ring. It is because of this property that when at the quarries refuse slates are thrown upon the dumps the sound produced is not unlike that made by the smashing of a large quantity of crockery.

Cleavability.—This test should be applied by an experienced workman. The block should be freshly quarried, unfrozen, and moist. The

¹ Full titles are given in the Economic Bibliography, included in Prof. Dale's paper. A useful bibliography of purely technical works on building stone, by Geo. P. Merrill, appears in the Annual Report of the Smithsonian Institution for the year ending June 30, 1886, pp. 519-520.

chisel should be very thin and about two inches wide. The cost of slate is closely related to the degree of its cleavability.

Cross fracture ("sculpting").—This is to determine the character of the "grain." This test should also be applied by an experienced hand to a large block several inches thick, with a stout chisel and a long-handled, heavy mallet. Jannetaz¹ published a method for determining with scientific precision the direction of the grain in slate when it is but obscurely shown on the cleavage surface. The slate is sawn in a direction parallel to its cleavage and one of the sawn surfaces is made exceedingly smooth and covered with an even and very thin coat of grease. The point of a red-hot platinum wire is applied to the slate opposite the center of the greased surface. The greased area reached by the heat will, in cooling, leave an oval outline, the long axis of which will show the direction of the grain, the heat having traveled more rapidly within the slate in the direction of the grain than in any other. He also made a disk of slate 5 inches in diameter of ordinary thickness, with a central perforation. This disk was fastened by the extremities of the diameter parallel to the grain and afterwards by that at right angles to the grain, and was made to vibrate by tapping the side of the perforation. The sound produced when the disk was fastened by the diameter at right angles to the grain was louder than when fastened by that parallel to it. In other words, the direction of the grain was that in which elasticity and vibration were greatest.

Character of cleavage surface.—The cleavage surface should be examined with an ordinary magnifying glass. A superior slate should scale along the cleavage surface into very thin chips with translucent edges. If the grain is pronounced it will appear in fine transverse lines. If false cleavage, which is fatal, be present, it can usually be detected on the cleavage surface. Ribbons, which are sometimes lines of weakness, should be noted. There is great difference in the smoothness of the surface in slates of different regions. Ordinarily the constituent minerals ought not to be visible. Minute lenses or crystals are not necessarily detrimental, but they retain dust and thus afford a foothold for mosses and other cryptogams, which gather moisture and thus aid the decomposition of the slate.

Presence of lime.—This can be determined by the application of cold dilute hydrochloric acid to the edges of a freshly quarried slate. Rapid effervescence implies presence of carbonate of lime; slow, that of a lesser quantity of it or of dolomite—carbonate of lime and magnesia.

Color and discoloration.—The color of the freshly quarried slate should be noted and compared with that of pieces exposed for several years to the weather, either on a roof or on the quarry dumps, or with that at the top of the quarry close to the gravel, although this last comparison may not always be perfectly conclusive. The value of slates is somewhat affected by the extent of their discoloration.

¹ Relations entre la propagation de la chaleur et l'élasticité sonore dans les roches, 1877, p. 417.

Presence of clay.—This should be tested by breathing upon a fresh and clean piece of slate and observing whether there is any argillaceous odor. The very best slate will not emit any such odor.

Presence of marcasite.—A slate containing lenses or crystals of a pale-yellowish metallic mineral which on exposure decomposes, forming a yellowish-white film and rusty spots, is poor.¹

Strength.—See Merriman's paper² for apparatus and method used in determining the modulus of rupture in pounds per square inch, which he finds in the best slates should range from 7,000 to 10,000 pounds. See also J. F. Williams's³ tests of compression and elastic limit applied to purple, red, and green slates from Rutland and Washington counties. His results show a limit of compression ranging from 8,040 to 24,760 pounds per square inch, and an elastic limit at from 4,850 to 10,260 pounds. Campbell and Donald⁴ give 20,000 pounds as the crushing weight for one cubic inch of slate. Wilkinson, in his *Practical Geology of Ireland*, gives 30,730 pounds as the crushing weight of the Killaloe slates.⁵ Watrin⁶ gives the maximum crushing weight of some French slates as 2,000 kilograms per square centimeter, but 1,700 as the average.

Toughness or elasticity.—Merriman finds the ultimate deflection in certain Pennsylvania slates, when placed on supports 22 inches apart, to range from 0.270 to 0.313 inch. Certain blue-black slates in Eldorado County, California, when split seven to the inch and 18 inches square, and fastened solidly at the two ends, are said to bend 3 inches in the center without any sign of fracture.⁷ J. F. Williams³ tested beams of slate from Rutland and Washington counties, 1 inch square and 10 inches long, with supports 6 inches apart. Bending without breaking was effected by from 770 to 1,200 pounds, and when the supports were placed 3 inches apart by from 1,710 to 2,400 pounds. The great elasticity of the slates of eastern New York and western Vermont is apparent to anyone visiting the shanties where the splitting is done.

Density, or specific gravity.—This is determined in the usual way, by weighing a piece of the slate in and out of water and dividing its weight out by the difference between its weight in and out. The specific gravity will be considerably affected by the amount of magnetite or pyrite. Merriman's tests of Pennsylvania slates give 2.761 to 2.817. Meyer's *Konversations-Lexikon*, 1894, gives 2.8 to 2.9 as the normal specific gravity of a good roofing slate.⁸

¹ See On marcasite and pyrite; a comparative study of the chemical behavior of pyrite and marcasite, by A. P. Brown: *Proc. Am. Phil. Soc.*, Vol. XXXIII, pp. 225-243, 1894.

² *Op. cit.* An extended abstract of Merriman's paper in the U. S. Geological Survey report on stone for 1897, and some data obtained by Prof. W. O. Crosby as to the strength of the Maine slates are presented.

³ *Op. cit.*

⁴ *Encycl. Brit.*, ninth ed., 1887.

⁵ Quoted by Hull; *op. cit.*

⁶ *Op. cit.*, pp. 192, 193.

⁷ California State Mining Bureau, Twelfth Report of State Mineralogist J. J. Crawford, September 15, 1894, p. 406.

⁸ See also p. 62.

Porosity.—This is best determined by drying, then weighing, then immersing for twenty-four hours and weighing again, in order to ascertain the percentage of water absorbed. Merriman takes a piece 3 by 4 inches, with rough edges, dries it in an oven at 135° F. for twenty-four hours, cools to the normal temperature of room, weighs, and immerses it for twenty-four hours, and weighs again. His tests of Pennsylvania slate showed from 0.099 to 0.303 per cent of absorption. Porosity is sometimes roughly indicated by immersing a roofing slate edgewise one-half in water and observing how far the water ascends by capillary attraction. In good slates it ought to rise but very little.

Reverdin and De la Harpe¹ state that slates are liable to deterioration from the chemical action of gases arising from woodwork beneath the slate, as well as from the action of the atmosphere, and that they are also liable to an increase of porosity by the physical action of changes of temperature and by the unequal conductivity of heat in the direction of cleavage and of grain. They state that the porosity in a fresh slate should be below 0.1 per cent and after treatment less than 0.2 per cent. Their somewhat elaborate method is this: For determining porosity as produced by acids, the slate is treated with 10 per cent cold acetic acid and the flask is made vacuous from time to time. The piece is then washed, dried, weighed, and immersed in diphenylamine in a thick-walled tube 12 by 3½ centimeters. The tube is exhausted, heated two hours in oil bath at 170° C., air pressure is restored, and heating continued for four to five hours at 150° C., after which the test pieces are removed, the diphenylamine wiped off with ether, and the increase in weight taken.

For determining porosity as produced by changes of temperature, the slate is heated in a wrought-iron tube for half an hour to 300° C., and the tube is then suddenly cooled by a stream of water for half an hour. This process is repeated twenty-four times, and the slate is then impregnated with diphenylamine and the procedure is as in previous tests.

Fresenius is accredited with a method of testing the effect of heat and cold on slate by saturating it with water and putting it for twenty-four hours in a freezing mixture and heating another from 250° to 350° C. for five or six hours and then immersing it in water. The porosity, strength, and elasticity of the pieces so treated should then be tested. Böttger points out that the greater the porosity of a slate the more damaging is the action of frost likely to be.¹

Corrodibility.—An important quality in roofing slates is their resistance to the acids of the atmosphere, particularly in cities, where gases increase its destructive power. Fresenius in 1868¹ suggested testing the weathering qualities of a slate by immersing it for three days in dilute sulphurous acid in a closed vessel. At the end of that time poor slates are softened or broken up into thin laminae or easily fractured, while good ones preserve both their density and hardness.

¹ Op. cit.

Merriman for the same purpose prepared a solution consisting of 98 parts of water, 1 part of hydrochloric acid, and 1 part of sulphuric acid. Pieces of slate 3 by 4 inches were carefully weighed, then immersed in the solution for sixty-three hours, then dried for two hours in the air of the laboratory, and weighed again. The loss in weight ranged from 0.374 to 0.619 per cent.

Microscopic analysis.—One of the most satisfactory tests of slate is the examination of a thin section of it under the microscope. A cubic inch thus tested will suffice to show the character of the cleavage, the presence of false cleavage, if any, the probable durability or indurability of the color, as well as the presence of any mineral constituents likely to affect its general durability. The specimen should be carefully selected, so as to fairly represent the general quality of the bed. It should be fresh, unfrozen, and about an inch thick across the cleavage. At least two sections should be prepared—although the more the better—one parallel to the cleavage and another at right angles to it, never diagonal to it. The sections should be exceedingly thin, much more so than ordinary sections of eruptive rocks, and the slide cover should be of the very thinnest kind, to admit the use of the highest objectives. Both slides should be examined first in ordinary light, then in polarized light with powers ranging from 140 to 700 diameters. The transverse section will show the quality of cleavage, the false cleavage, if any, and under polarized light will, as pointed out by Sorby and others, show whether the specimen is a slate or a shale or something between the two by the entire matrix becoming, in a true slate, four times dark and four times light in complete rotation. Sections parallel to the cleavage reveal the amount of carbonate and indicate the probable amount of discoloration by exposure. Both sections under incident light will show pyrite if any exists.

Chemical analysis.—This, in order to give a correct idea of the composition of the slate, should not be partial but complete.¹ Such an analysis should then be compared with complete analyses of the best slates of like color, and before a final conclusion is reached as to the value of the slate its microscopic analysis and the results of the tests of its strength, elasticity, porosity, and corrodibility should be considered in connection with its chemical analysis. Merriman concludes from six different kinds of tests applied to each of 24 specimens of old Bangor and Albion (Pennsylvania) slates, as well as from the results of several general chemical analyses, that—

The strongest slate stands highest in weathering qualities, so that a flexural test affords an excellent index of all its properties, particularly if the ultimate deflection and the manner of rupture be noted. The strongest and best slate has the highest percentage of silicates of iron and alumina, but is not necessarily the lowest in carbonates of lime and magnesia. Chemical analyses give only imperfect conclusions regarding the weathering qualities of slates and do not satisfactorily explain their physical properties.²

¹ See, on the advantage of complete analysis, Principles and methods of analysis applied to silicate rocks, by W. F. Hillebrand, Bull. U. S. Geol. Survey, No. 148; Analyses of rocks and analytical methods, Clarke and Hillebrand, pp. 1-64, 1897.

² Op. cit.

Reverdin and de la Harpe¹ also call attention to the fact that good slate may have a high per cent of calcium carbonate and that others free from it may be poor, and that the presence of pyrite is not necessarily a bad indication, for it may not decompose. This statement needs modification, however, by adding that marcasite even in small quantities is very deleterious, for it decomposes very readily.²

Besides these tests there are a few others which are of scientific rather than economic importance. Umlauf suggests heating small splinters of slate under the blowpipe to determine the presence of pyrite and carbon and to ascertain the relative fusibility of different slates; also the test with bead of borax or phosphate of soda and ammonia to determine the presence of iron. He recommends putting a splinter of slate in pure hydrochloric acid in a watch glass and after evaporation examining the precipitate microscopically; also, the application of the same treatment to a splinter after fusion with the blowpipe. He recommends also the application of the ordinary mineralogical tests for hardness; e. g., scratching the slate with calcite and fluorite.

Hutchins finds that the presence of chlorite minerals can be detected by heating the slate to dull redness, thus dehydrating and discoloring those minerals, then preparing a thin section of the slate so treated and comparing it with sections of the normal rock.

GLOSSARY OF GEOLOGICAL AND QUARRY TERMS.

As this report may be consulted for economic or other purposes by persons unfamiliar with geological science, a number of the commoner geological (mostly structural) terms used in it are here explained, and for the benefit of geologists some of the terms in common use among the quarrymen of the region are translated into scientific ones. Some of these quarry terms were given by Speer in the Report of the Tenth Census, but the list has been enlarged.

ANTICLINE. The arch part of a folded bed.

BACK JOINT. Joint plane more or less parallel to the strike of the cleavage and frequently vertical.

BED. A continuous mass of material deposited under water at about one time.

BLIND JOINT. Obscure bedding plane.

BOTTOM JOINT. Joint or bedding plane horizontal or nearly so.

BRECCIA. Rock made up of angular fragments produced by crushing and then recemented by infiltrating mineral matter.

CLASTIC. Constituted of rocks or minerals which are fragments derived from other rocks.

CLEAVE. Slaty cleavage.

DIAGONAL JOINTS. Joints diagonal to the strike of the cleavage.

DIP. The degree and the direction of the inclination of a bed, cleavage plane, joint, etc.

DIP JOINT. Vertical joints about parallel to the direction of the cleavage dip.

DIKE. Molten material erupted through a narrow fissure.

END JOINT. Vertical joint about parallel to the direction of the cleavage dip.

EROSION. The "wear" of a rock surface by natural mechanical or chemical agencies.

¹ Op. cit.

² See under tests, p. 73.

FALSE CLEAVAGE. A secondary slip cleavage superinduced on slaty cleavage.

FAULT. A fracture resulting in a dislocation of the bedding or cleavage, one part sliding up or down, or both changing positions along the fracture.

FLINTS. A term applied alike to quartz veins or beds of quartzite.

GRAIN. An obscure vertical cleavage usually more or less parallel to the end or dip joints.

HOGBACKS. Zones of shearing.

PITCH. The inclination of the axis of a fold of rock.

POST. A mass of slate traversed by so many joints as to be useless. This term is also used to denote bands of hard rock.

RIBBON. A line of bedding or a thin bed appearing on the cleavage surface and sometimes of a different color.

SCULPING. Fracturing the slate along the grain, i. e., across the cleavage.

SHEAR ZONE. Hogback.

SLANT. Longitudinal joint more or less parallel to cleavage and often slickensided.

SLICKENSIDES. Surface of bed or joint plane along which the rock has slipped, polishing and grooving the surfaces.

SLIP. Occasional joint crossing the cleavage, but of no great continuity. Slips are not infrequently fault planes.

SLIP CLEAVAGE. Microscopic folding and fracture accompanied by slippage; quarrymen's "false cleavage."

SPLIT. Slaty cleavage.

STRATIFICATION. Bedding, in distinction from cleavage.

STRIKE. Direction at right angles to the inclination of a plane of bedding, cleavage, jointing, etc.

STRIKE JOINT. Joint parallel to the strike of the cleavage.

SYNCLINE. The trough part of a fold of rock.

TOP. The weathered surface of a slate mass, or the shattered upper part of it.

WAVERS. Annelid trails.

WILD ROCK. Any rock not fit for commercial slate.

SANDSTONE.

PRODUCTION.

The following table shows the output of sandstone in the United States for the year 1898:

Sandstone production in 1898, by States.

State.	Value.	State.	Value.
Alabama	\$27,882	Montana	\$3,683
Arizona	57,444	New Jersey	257,217
Arkansas	24,825	New Mexico	3,500
California	338,908	New York	566,133
Colorado	89,637	North Carolina	9,100
Connecticut	215,733	Ohio	1,494,746
Illinois	13,758	Oregon	7,864
Indiana	45,342	Pennsylvania	478,451
Iowa	7,102	South Dakota	9,000
Kansas	19,528	Texas	77,190
Kentucky	72,525	Utah	15,752
Louisiana	200,500	Washington	15,575
Maryland	13,646	West Virginia	14,381
Massachusetts	91,287	Wisconsin	80,341
Michigan	222,376	Wyoming	6,382
Minnesota	175,810	Total	4,724,412
Missouri	148,795		

The following table gives the value of the sandstone output, by States, for the years 1890 to 1898:

Value of sandstone, by States, from 1890 to 1898.

State.	1890.	1891.	1892.	1893.
Alabama	\$43,965	\$30,000	\$32,000	\$5,400
Arizona	9,146	1,000	35,000	46,400
Arkansas	25,074	20,000	18,000	3,292
California	175,598	100,000	50,000	26,314
Colorado	1,224,098	750,000	550,000	126,077
Connecticut	920,061	750,000	650,000	570,346
Florida	(a)			
Georgia	(a)		2,000	
Idaho	2,490		3,000	2,005
Illinois	17,896	10,000	7,500	16,859
Indiana	43,983	90,000	80,000	20,000
Iowa	80,251	50,000	25,000	18,347
Kansas	149,289	80,000	70,000	24,761
Kentucky	117,940	80,000	65,000	18,000
Maryland	10,605	10,000	5,000	360
Massachusetts	649,097	400,000	400,000	223,348
Michigan	246,570	275,000	500,000	75,547
Minnesota	131,979	290,000	175,000	80,296
Missouri	155,557	100,000	125,000	75,701
Montana	31,648	35,000	35,000	42,300
Nevada	(a)			
New Hampshire	3,750			
New Jersey	597,309	400,000	350,000	267,514
New Mexico	186,804	50,000	20,000	4,922
New York	702,419	500,000	450,000	415,318
North Carolina	12,000	15,000		
Ohio	3,046,656	3,200,000	3,300,000	2,201,932
Oregon	8,424		35,000	
Pennsylvania	1,609,159	750,000	650,000	622,552
Rhode Island	(a)			
South Dakota	93,570	25,000	20,000	36,165
Tennessee	2,722			
Texas	14,651	6,000	48,000	77,675
Utah	48,306	36,000	40,000	136,462
Vermont	(a)			
Virginia	11,500	40,000		3,830
Washington	75,936	75,000	75,000	15,000
West Virginia	140,687	90,000	85,000	46,135
Wisconsin	183,958	417,000	400,000	92,193
Wyoming	16,760	25,000	15,000	100
Total	10,816,057	8,700,000	8,315,500	5,295,151

a Sandstone valued at \$26,109 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 1898—Continued.

State.	1894.	1895.	1896.	1897.	1898.
Alabama	\$18,100	\$31,930	\$48,000	\$3,000	\$27,882
Arizona		20,000	10,000	15,000	57,444
Arkansas	2,365	13,228	1,400	3,161	24,825
California	10,087	11,933	7,267	4,035	358,908
Colorado	69,105	63,237	58,989	60,847	89,637
Connecticut	322,034	397,853	426,029	364,604	215,733
Georgia	11,300		1,250		
Idaho	10,529	6,900	16,060		
Illinois	10,732	6,558	15,061	14,250	13,758
Indiana	22,120	60,000	32,847	35,561	45,342
Iowa	11,639	5,575	12,351	14,771	7,102
Kansas	30,265	93,394	18,804	20,953	19,528
Kentucky	27,868	25,000		40,000	72,525
Louisiana				8,000	200,500
Maryland	3,450	16,836	10,713		13,646
Massachusetts	160,231	339,487	304,361	194,684	91,287
Michigan	34,066	159,075	111,321	171,127	222,376
Minnesota	8,415	74,700	202,900	158,057	175,810
Missouri	131,687	100,000	51,144	57,583	48,795
Montana	16,500	31,069	3,250	25,644	3,683
New Jersey	217,941	111,823	126,534	190,976	257,217
New Mexico	300	2,700			3,500
New York	450,992	415,644	223,175	544,514	566,133
North Carolina		3,500	13,250	11,500	9,100
Ohio	1,777,034	1,449,659	1,679,265	1,600,058	1,494,746
Oregon					7,861
Pennsylvania	349,787	500,000	446,926	380,813	478,451
South Dakota	9,006	26,100	37,077		9,000
Tennessee			4,100		
Texas	62,350	97,336	36,000	30,030	77,190
Utah	15,428	5,000	7,860	7,907	15,752
Virginia	2,258				
Washington	6,611	14,777	11,090	16,187	15,575
West Virginia	63,865	40,000	24,693	47,288	14,381
Wisconsin	94,888	78,000	65,017	33,620	80,341
Wyoming	4,000	10,000	16,465	11,275	6,382
Total	3,935,847	4,211,314	4,023,199	4,065,445	4,724,412

Inspection of this table shows that the output has increased over 1897, for which year the value was \$4,065,445, while for 1898 it was \$4,724,412.

THE SANDSTONE INDUSTRY IN THE INDIVIDUAL STATES.

ALABAMA.

As compared with 1897 the past year shows an increase from \$3,000, as the value of the output in 1897, to \$27,882 in 1898. This was due in part to the erection of coke ovens in the latter year. Prospects are much better than they have been for years.

ARIZONA.

Owing to increased consumption of sandstone for railroad bridges, the output increased in value from \$15,000 in 1897 to \$57,444 in 1898. The stone is of good quality, red in color, and weighs 158 pounds to the cubic foot.

ARKANSAS.

Increased consumption of sandstone for riprap raised the value of the output from \$3,161 in 1897 to \$24,825 in 1898.

CALIFORNIA.

Exceptional use of sandstone for jetties in California accounts largely for the production of an amount valued at \$358,908.

COLORADO.

Business was much better in 1898 than in 1897, the valuation having increased from \$60,847 to \$89,637. Prospects for the future are unquestionably good. Most of the producers speak in a more hopeful tone than for several years past.

CONNECTICUT.

Although 1898 was a much better year for sandstone in most of the productive States, it was not so for Connecticut. The value of the output in 1897 was \$364,604, and for 1898 \$215,733. This is accounted for by a variety of causes, among which strikes may be especially mentioned. There seems to be no good reason, however, for a continuation of the reduced production.

ILLINOIS.

But little was accomplished in sandstone production during the year. The output, however, never has been large.

INDIANA.

Demand for sandstone was very decidedly better with some of the larger producers than in 1897. As a consequence the output increased from a valuation of \$35,561 in 1897 to \$45,342 in 1898. Indications for 1899 are excellent.

IOWA.

Sandstone quarrying has never amounted to much in Iowa. The value of the output in 1898 was \$7,102.

KANSAS.

Values were \$20,953 and \$19,528, respectively, for 1897 and 1898. The product was largely used for flagstone.

KENTUCKY.

Conditions improved markedly during the year, resulting in an increase from a valuation of \$40,000 in 1897 to \$72,525 in 1898.

LOUISIANA.

Sandstone was quarried for jetty work at Sabine Pass, Texas, from quarries in Louisiana during 1898. These operations constituted an important factor in the production of a total amount of sandstone valued at \$200,500.

MARYLAND.

No sandstone at all was reported for Maryland in 1897, while in 1898 an amount valued at \$13,646 was quarried.

MASSACHUSETTS.

Business was poor among the sandstone producers of the State during 1898. The most important quarries are at East Long Meadow. The producers seem somewhat discouraged; the conditions are similar to those which have prevailed among the producers of sandstone in Connecticut. The product was valued at \$91,287 in 1898.

MICHIGAN.

A number of large concerns in Michigan report a very much better business in 1898, so that the valuation increased from \$171,127 in 1897 to \$222,376 in 1898.

MINNESOTA.

The value of the output in 1897 was \$158,057; in 1898, \$175,810. Much improved conditions are reported by almost all of the producers, included among whom are the operators of the unique jasper quarries in Pipestone County.

MISSOURI.

The output of sandstone fell slightly below that of 1897. There are but few quarries of sandstone in the State. The output of 1898 was valued at \$48,795.

NEW JERSEY.

The value of the sandstone product in 1897 was \$190,976. Producers report conditions generally better for 1898. The value of the output for the latter year was \$257,217.

NEW YORK.

An improvement is characteristic of the year 1898, when a product valued at \$566,133 was quarried. The value of the output in 1897 was \$544,514. Prospects for 1899 are excellent.

OHIO.

The value of the sandstone output in 1897 was \$1,600,058. In 1898 production declined to a valuation of \$1,489,579. Quite a number of the smaller operators ceased operation altogether during the year, and less business was done by a number of the largest producers. It seems quite certain, however, that a larger volume of business will be done in 1899.

OREGON.

A small amount of sandstone quarrying was done in 1898; the production of sandstone is somewhat irregular from year to year.

PENNSYLVANIA.

Production increased from a valuation of \$380,813 in 1897 to \$478,451 in 1898. A full account of the sandstone industry in Pennsylvania was published in the report for 1896.

SOUTH DAKOTA.

There is plenty of good red sandstone in South Dakota, but comparatively little is as yet quarried—\$9,000 worth in 1898.

TEXAS.

The value of the output was doubled in 1898, increasing from \$30,030 in 1897 to \$77,190.

UTAH.

But little sandstone quarrying is done in Utah, although there is an abundance of good material there, some of which has been tested scientifically and by practical use.

WASHINGTON.

The value of the output in 1898 was \$15,575—about the same as in 1897. Bellingham Bay stone, quarried at Chuckanut, is one of the most interesting from the commercial standpoint. This stone has been thoroughly tested at the Watertown Arsenal.

WEST VIRGINIA.

Production fell off from a valuation of \$47,288 in 1897 to \$14,381 in 1898. Among a number of quarries in the State are some that have achieved a high reputation as bridge stone.

WISCONSIN.

The value of the output in 1898 was \$80,341; this is the highest figure reached since 1894.

WYOMING.

But little was done in 1898.

LIMESTONE.

PRODUCTION.

The following table shows the production of limestone in the United States in 1898, by States and uses:

Production of limestone in the United States in 1898, by States, and uses.

State or Territory.	Building purposes.	Paving and road making.	Rdprap.	Made into lime.	Stone sold to lime burners.	Flux.	Total.
Alabama	\$27,000	\$4,500	\$600	\$115,482	\$300	\$94,413	\$242,285
Arizona	1,200			582			1,782
Arkansas	14,675	900	7,070	31,728			54,373
California	91	21,983		189,525	a 8,533	9,597	229,729
Colorado	21,433		6,000	27,125	72	54,680	109,310
Connecticut				141,245		812	142,057
Florida		36,300	37,470	17,500			91,330
Georgia				57,803			57,803
Idaho	50		500	2,530			3,080
Illinois	788,548	396,302	73,374	127,156	609	35,092	1,421,072
Indiana	1,083,571	253,731	16,046	190,540	4,500	138,184	1,686,572
Iowa	280,832	87,079	39,507	116,715	413		524,546
Kansas	147,548	102,342	51,073	4,642			305,605
Kentucky	20,040	42,185	591	10,873		10,271	83,900
Maine				1,279,226	4,242		1,283,468
Maryland	10,768	155,714	276	263,449	3,231	215	433,653
Massachusetts	7,316	326	66	160,692	5,200	1,222	174,822
Michigan	21,266	43,809	3,000	79,648	110,600	13,800	271,523
Minnesota	272,009	21,579	24,306	27,236	380	175	345,685
Missouri	238,553	145,498	36,985	297,401		16,838	735,275
Montana				7,200		55,096	62,296
Nebraska	46,256	29,501	896	1,000		240	78,493
New Jersey	256	1,066		118,760	175	25,700	146,611
New York	553,614	413,410	12,064	482,936	28,027	543,885	1,533,906
North Carolina			450	1,155			1,605
Ohio	221,440	260,957	51,245	911,482	17,936	210,000	1,673,160
Oklahoma Territory	3,000						3,000
Oregon	2,000			5,000	480		7,480
Pennsylvania	190,394	256,961	24,613	1,201,352	107,410	905,526	2,746,256
Rhode Island				10,215			10,215
South Carolina		500	500	33,000			34,000
South Dakota				613		26,245	26,858
Tennessee	21,197	34,011	355	120,448	3,213	3,178	182,402
Texas	7,039	487	1,633	38,531	100	22,531	70,321
Utah	3,996			3,606		4,125	11,721
Vermont	1,000	400		172,750			174,150
Virginia	180	16,250		83,087	4,515	73,820	182,852
Washington				136,129	1,561	2,529	140,239
West Virginia	1,017	403		49,813	4,934		56,167
Wisconsin	167,875	111,726	30,694	367,720	483	19,956	698,454
Total	4,154,158	2,438,520	419,414	6,886,549	3,061,325	1,834,090	16,059,056

a Sold to sugar refineries.

b Includes \$15,742 used for chemical purposes, pulp mills, glass factories, etc.

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

Value of limestone, by States, from 1890 to 1898.

State or Territory.	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
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 \$77,335 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 1898—Continued.

State.	1890.	1894.	1895.
Alabama	\$205,000	\$210,269	\$222,424
Arizona	15,000	19,810	24,159
Arkansas	7,611	38,228	47,376
California	288,626	288,900	322,211
Colorado	60,000	132,170	116,355
Connecticut	155,000	204,414	154,333
Florida	35,000	30,639	10,550
Georgia	34,500	32,000	12,000
Idaho	1,000	5,315	7,829
Illinois	2,305,000	2,555,952	1,687,662
Indiana	1,474,635	1,203,108	1,658,976
Iowa	547,000	616,630	449,501
Kansas	175,173	241,039	316,688
Kentucky	203,000	113,934	154,130
Maine	1,175,000	810,089	700,000
Maryland		350,000	200,000
Massachusetts	156,528	195,982	75,000
Michigan	53,282	336,287	424,589
Minnesota	208,088	291,263	218,733
Missouri	861,563	578,802	897,318
Montana	4,100	92,970	95,121
Nebraska	158,927	8,228	7,376
New Jersey	149,416	193,523	150,000
New Mexico		4,910	3,375
New York	1,103,529	1,378,851	1,043,182
North Carolina			
Ohio	1,848,063	1,733,477	1,568,713
Oklahoma Territory			
Oregon	15,100		970
Pennsylvania	1,552,336	2,625,562	3,055,913
Rhode Island	24,800	20,433	
South Carolina	22,070	25,100	
South Dakota	100	3,663	4,000
Tennessee	126,089	188,664	156,898
Texas	28,100	41,526	62,526
Utah	17,446	23,696	22,503
Vermont	151,067	408,810	300,000
Virginia	82,685	284,547	268,892
Washington	139,862	59,148	75,910
West Virginia	19,184	43,773	42,892
Wisconsin	543,283	798,406	750,000
Wyoming			650
Total	13,947,223	16,190,118	15,308,755

Value of limestone, by States, from 1890 to 1898—Continued.

State.	1896.	1897.	1898.
Alabama.....	\$180,921	\$221,811	\$242,295
Arizona.....	18,470	11,522	1,782
Arkansas.....	30,708	44,222	54,373
California.....	143,865	308,925	229,729
Colorado.....	65,063	79,256	109,310
Connecticut.....	138,945	178,410	142,657
Florida.....	16,982	18,889	91,330
Georgia.....	29,081	32,000	57,803
Idaho.....	5,662	15,538	3,080
Illinois.....	1,261,359	1,483,157	1,421,072
Indiana.....	1,638,499	2,012,608	1,686,572
Iowa.....	410,037	480,572	524,546
Kansas.....	158,112	208,889	305,605
Kentucky.....	135,967	40,815	83,960
Maine.....	608,077	742,877	1,283,468
Maryland.....	264,278	181,637	433,653
Massachusetts.....	118,622	126,508	174,822
Michigan.....	109,427	215,177	271,523
Minnesota.....	228,992	236,397	345,685
Missouri.....	802,968	1,018,202	735,275
Montana.....	83,927	37,300	63,196
Nebraska.....	10,655	42,359	78,493
New Jersey.....	134,213	141,646	146,611
New Mexico.....			
New York.....	1,591,906	1,607,780	1,533,936
North Carolina.....			1,605
Ohio.....	1,399,412	1,486,550	1,673,160
Oklahoma Territory.....			3,000
Oregon.....	1,600		7,480
Pennsylvania.....	2,104,774	2,327,870	2,746,256
Rhode Island.....	11,589	11,555	10,215
South Carolina.....	26,000	30,000	34,000
South Dakota.....	3,126	3,895	26,858
Tennessee.....	157,176	113,774	182,402
Texas.....	77,252	57,258	70,321
Utah.....	9,358	9,250	11,721
Vermont.....	147,138	165,657	174,150
Virginia.....	182,640	192,972	182,852
Washington.....	83,742	126,877	140,239
West Virginia.....	59,113	61,546	56,167
Wisconsin.....	552,921	641,232	698,454
Wyoming.....			
Total.....	13,022,637	14,804,933	16,039,056

THE LIMESTONE INDUSTRY IN THE INDIVIDUAL STATES.

ALABAMA.

The output of limestone in Alabama in 1898 was valued at \$242,295. This is the largest figure reached since 1892. The figure for 1897 was \$221,811. The limestone is mostly used for lime burning and blast-furnace flux. The value of the lime made was \$115,482 and the blast-furnace flux \$94,413. The resumption of production by a number of blast furnaces during the year was one of the causes for increased output. The value of the flux produced was more than twice as great as that of the product of 1897, while the value of the lime produced declined somewhat. Indications for 1899 are reported as encouraging by several large producers.

ARIZONA.

Very little was done in 1898, the product being valued at only \$1,782.

ARKANSAS.

The value of the limestone output increased from \$44,222 in 1897 to \$54,373 in 1898. Most of the product is burned into lime, the value of which was \$31,728. Almost all of the remainder was used for building.

CALIFORNIA.

The value of the limestone product in 1898 was \$229,729; of this sum, \$189,525 was the value of the lime made. The year can not be regarded as a prosperous one, since the output in 1897 was valued at \$308,925.

COLORADO.

The total value of the output was \$109,310. The value of the flux produced was \$54,680. The remainder was about equally divided between lime and building purposes. During the early part of the year business was poor, but a sudden improvement characterized the latter part. Indications for 1899 are fair.

CONNECTICUT.

Connecticut has for a long time been prominent as a lime-producing State, particularly so on account of the fine quality of the lime made. All of the product was burned into lime. The abundance of granite in the State is probably the reason why no limestone is used for building.

FLORIDA.

For a long time Florida was entirely omitted from the list of stone-producing States, but in 1898 it appears with quite an increase over any former year, namely, a production valued at \$91,330. This was almost equally divided between road making and riprap. A small quantity was burned into lime.

GEORGIA.

The limestone quarried in Georgia was entirely burned into lime, the value of which in 1898 was \$57,803. This is more than has ever been accomplished in the State in any one year before. The stone interests in Georgia center in its granite and marble more than in any other kind of stone.

IDAHO.

The value of the product in 1898 was \$3,080, practically all of which was the value of lime made.

ILLINOIS.

The value of the limestone output in Illinois declined from \$1,483,157 in 1897 to \$1,421,072 in 1898. More than one-half of this value is that of stone used for building. This comes largely from quarries at Lemont and Joliet. One-third of the amount went for paving and road making, while the remainder was divided between lime flux and riprap. Some years ago Illinois produced more limestone for building purposes than any other State in the Union, but in recent years it has been succeeded by Indiana, owing to the large production of the Bedford oolitic stone. The early part of the year was characterized by poor business, but a decided revival took place in the last few months, making the outlook for 1899 much more encouraging. Labor troubles at Joliet interfered with production quite materially. Almost all of the producers in the Joliet and Lemont regions report improved conditions, particularly for the latter part of the year.

INDIANA.

Indiana is of especial interest among the States producing limestone, from the fact that it stands first in the list for the amount of stone devoted to building purposes. The value of the total output in 1898 was \$1,686,572. Of this amount over \$1,000,000 represents the value of the building stone, which comes largely from the celebrated Bedford region, which yields oolitic stone. It is scarcely necessary to say that the Bedford oolitic stone is popular over a wide range of the United States as a stone of light color.

IOWA.

The value of the limestone output in 1898 was \$524,546, a gain of about \$44,000 over 1897. About half of the product went for building purposes, one-fourth is the value of lime made, while the remainder went mainly for paving and road making. The cooperation of the Iowa State Geological Survey aided very materially in the collection of the Iowa statistics.

KANSAS.

The value of the output increased from \$208,889 in 1897 to \$305,605 in 1898. One-half the product went for building purposes, one-third for paving and road making, and the remainder went mainly for riprap, a small quantity only being made into lime. The output was the largest since 1895. Indications for 1899 are very good.

KENTUCKY.

The output of limestone in Kentucky was practically doubled in 1898 as compared with 1897. Most of the product went for road making; the rest was divided between lime and building.

The most interesting limestone in the State, from the standpoint of building, is the Bowling Green oolite, which, however, is at present not quarried in very large quantity. Quite a number of the producers report encouraging prospects for 1899.

MAINE.

All of the limestone quarried in Maine is burned into lime.

The total value of all the lime produced was \$1,279,226. Maine stands at the head of the lime-producing States of the Union, Pennsylvania standing second with an output of \$1,201,352. The lime of Maine comes chiefly from Rockland and vicinity and Thomaston, where a particularly pure limestone is quarried. The number of casks of lime produced was 2,057,052. An average value of 62 cents per cask is thus indicated. The value of the output is somewhat less than twice that of 1897. It is therefore very evident that the industry was in a flourishing condition throughout the year, but the best conditions prevailed toward the close of the year. The tendency of prices was downward.

MARYLAND.

The value of the total output of limestone in Maryland was \$433,653. More than half of this is the value of lime made; the rest of the output was devoted mainly to paving and roadmaking. There was a very marked increase over the output for 1897, which was valued at \$181,637.

MASSACHUSETTS.

The total value of the output in 1898 was \$174,822. Of this figure \$160,692 is the value of lime made. It is therefore evident that most of the stone is burned into lime.

MICHIGAN.

The value of the limestone output of Michigan for 1898 is \$271,523. About two-thirds of this was burned into lime and the rest was divided into building and paving. The value of the output in 1897 was \$215,177; quite a decided increase is thus evident.

MINNESOTA.

The output of limestone in Minnesota is the largest since 1892, and about 50 per cent greater than 1897. The figures for 1898 are \$345,685. Most of the stone is devoted to building purposes. Most of the reports speak very encouragingly of the outlook for 1899.

In the December, 1898, number of De Lestry's Western Magazine appeared an article on the building stones of Winona, Minnesota. The stone quarried here is a dolomite varying in color from buff to light gray, though there are also found layers nearly white in color. Its crushing strength is said to be 16,250 pounds per square inch and weight per cubic foot 153.1 pounds. The stone has been used in buildings at Winona since 1862. It has also been adopted for sidewalks. For all purposes to which it has been applied it has given entire satisfaction, both for durability and appearance. A number of churches and public buildings have been built of it.

MISSOURI.

The value of the limestone output of Missouri declined from \$1,018,202 in 1897 to \$735,275 in 1898. The value of the lime made is \$297,401, while the value of stone devoted to building was \$238,553. The remainder was divided up among paving and roadmaking, riprap and flux. Many of the producers report much improved business for the latter part of the year and the first of 1899. Doubtless the current year will show considerable gain.

MONTANA.

Aside from \$7,200 worth of lime, the entire output of limestone in 1898 went for fluxing purposes. The industry has never been large in Montana, and most of the product goes as a flux each year.

NEBRASKA.

Quite a notable increase marked the year 1898. The value of the output for 1897 was \$42,359; in 1898, \$78,493. This was divided between building and roadmaking, but little being burned into lime.

NEW JERSEY.

For several years past the value of the limestone output in New Jersey has been quite constant. Most of it is burned into lime, while the rest is used for blast-furnace flux. The value of the product in 1898 was \$146,611.

NEW YORK.

The value of the limestone output in New York fell off from \$1,697,780 in 1897 to \$1,533,936 in 1898. The stone is about equally divided between building purposes, paving and roadmaking, and lime.

OHIO.

The value of the output in Ohio—\$1,673,160—is the highest attained since 1894. A decided gain over 1897 has been made. The figures for 1897 were \$1,486,550. The output is for the greater part burned into lime, the value of which in 1898 was \$911,482. For paving and road-making the value of stone used was \$260,957; for building purposes, \$221,440, and for flux, \$210,000. In magnitude of output of limestone Ohio stands second, Pennsylvania being first, with an output of nearly three millions. The lime industry in Ohio is a very extensive one, and the quality of lime made is in many cases very superior. Most of the producers report decidedly improved business.

PENNSYLVANIA.

Pennsylvania stands first for the magnitude of its limestone output, the value of which in 1898 was \$2,746,256, a decided gain over 1897, when the value was \$2,327,870. The value of the lime made during the year 1898 was \$1,201,352. The value of flux was \$965,526. For paving and roadmaking the value of crushed stone was \$256,961. Quite a large proportion of the lime made is used for agricultural purposes.

RHODE ISLAND.

Rhode Island has never produced much limestone in any year, it being distinctively a granite State. About \$10,000 worth of lime is annually produced.

SOUTH CAROLINA.

About \$30,000 worth of output is secured in South Carolina every year. This figure represents the value of lime, with the exception of a very small amount for roadmaking.

SOUTH DAKOTA.

The only purpose for which limestone is quarried in South Dakota appears to be flux. The value of the output in 1898 was \$26,858.

TENNESSEE.

There was a very encouraging increase in the value of output in Tennessee in 1898, the total reaching \$182,402, against \$113,774 in 1897. Most of the product is burned into lime.

TEXAS.

The value of the limestone output in Texas in 1898 was \$70,321. This was about equally divided between lime and blast-furnace flux.

VERMONT.

The value of the total output in 1898 in Vermont was \$174,150. Practically all of this was the value of lime made.

VIRGINIA.

The limestone industry in Virginia has not yet regained its former prosperous condition, as the output is still markedly below what it was in 1894. It was about equally divided between lime and blast-furnace flux. Reports indicate that better conditions will prevail during 1899 than have been known in several years.

WASHINGTON.

Something of a gain was made during 1898, namely, from \$126,877 in 1897 to \$140,239 in 1898. Almost all of this figure represents the value of lime made.

WEST VIRGINIA.

The value of the limestone output in 1898 was \$56,167. Very nearly all of this is the value of lime made. The industry has not varied a great deal in general prosperity for the last five or six years, although it is much lower than 1892.

WISCONSIN.

The limestone industry in Wisconsin is one of considerable magnitude, the total value of the output being generally about three-quarters of a million. About one-half of this value is the value of lime made. The other half is divided between building purposes and road making.

TESTS AND ANALYSES OF STONE.

In the selection of all kinds of material for structural use it is becoming more and more customary to test such material, and to make the final selection on the basis of results so secured. It is, of course, unnecessary to state that if a given material has already demonstrated its fitness for a certain use by years of experience with it in that capacity, no results of scientific test should be considered as in any way capable of offsetting these results of actual experience; but in a country as young as the United States enough time has not yet elapsed in the use of stone as a building material to afford, in more than a few cases, a sufficient amount of such knowledge as results from long-continued use. As an example of a stone already sufficiently well known not to require further special tests, Quincy granite may be cited. This stone, by its hardness and susceptibility to high polish, and the contrast offered between polished and hammered surface, has demonstrated its fitness for use as a monumental stone. Similar statements might be made in regard to Westerly granite and other long-quarried and well-known materials.

When, however, a new material comes up for consideration it is desirable to learn of its qualities by quicker processes than those which

depend upon actual use. There have, therefore, been devised a number of methods of testing stone which may be quickly carried out and which are of various degrees of value, according to the nature of the stone tested and the use to which it is to be put. The practice of making these tests of stone is of such comparatively recent date that it can hardly be said that the particular tests are so well understood as to be beyond criticism either in regard to the nature of the test itself or in the method of carrying it out. There is, moreover, a great lack of agreement among testing experts, both as to what tests should be applied to a given stone and as to details in the methods of applying these tests. In some cases physical tests seem to be all that are necessary to furnish the needful information without any chemical analysis whatever. In other cases it is quite generally conceded that physical tests should be supplemented by more or less complete chemical analyses. At the present time the uses to which stone is put are quite different from those involving it as a structural material. Thus limestone is used in enormous quantities for burning into lime and as a flux in metallurgical operations. Limestone for such uses may be taken from the same quarry that furnishes building stone, and is thus quarried by the same methods as apply to the production of the building stone. It can not therefore well be considered apart from that which is devoted to structural use. If limestone is to be burned into lime it is of course evident that the physical strength of the stone so used is of no moment whatever, but a knowledge of the chemical composition is absolutely essential. The same idea applies to limestone to be used as a blast-furnace flux.

Again, although a stone to be used for structural purposes may show great physical strength, it may, nevertheless, contain minerals which by decomposition from atmospheric agencies may develop in the entire mass weaknesses that would in course of time make the use of the stone undesirable. To detect the presence of such minerals chemical analysis may be resorted to in some cases, or, better still, this, together with a microscopical examination of thin sections, by which it is possible to detect minerals as such, even though the amount present may be extremely minute. The application of microscopical examination as a means of studying stone in relation to its technical applications is of recent date and as yet is used only to a limited extent.

Among the tests most commonly applied to stone which is to be used for structural purposes is the crushing-strength test. This gives in general a good idea not only of the power of the stone to support without fracture the superstructure that may rest upon it, but also of the homogeneity and all-round durability of the material. Other tests of value include transverse strength, porosity, corrodibility, specific gravity, and resiliency.

A study of the tests presented in detail in this report will, it is believed, convince any intelligent engineer that there is need for an

agreement among the members of the engineering profession as to the tests which are called for by each kind of stone, and also an understanding as to the best manner of carrying out each individual test.

The tests in the following pages have been obtained in most instances from the stone producers direct. It will be noticed that in nearly every case the source of the stone, the name of the producer, and the name of the expert who made the test have been given. Quite a number of tests have been omitted from the report because of lack of knowledge as to the source of the stone or as to the name of the expert.

For convenience of reference the tests have been arranged according to the State in which the stone was quarried.

TESTS AND ANALYSES OF STONE IN INDIVIDUAL STATES.

ALABAMA.

The following table gives a number of results of analysis of limestones and lime:

Analyses of limestone quarried in Alabama.

Name of firm quarrying stone.	Location of quarry.		Name and address of analyst.	Substances determined.							
	Town.	County.		Calcium carbonate, CaCO ₃	Magnesium carbonate, MgCO ₃	Oxides of iron and aluminum.	Calcium oxide, CaO.	Silica, SiO ₂ .	Carbon dioxide, CO ₂ .	Total.	
Anniston Lime Works Co.	Anniston.....	Etowah.....	Wm. Makemson, Anniston, Ala.	Per ct. 98.76	Per ct. Trace	Per ct. 0.36	Per ct. 0.74			Per cent. 99.86	
A. P. Birch.....	Blount Springs ..	Blount.....	Dr. W. B. Phillips, Birmingham, Ala.	99.16		.40		.50		100.00	
Longview Lime Works (No. 1).	Longview	Shelby.....	Eugene A. Smith, State geologist.	99.11	0.75	.13		5.39		100.38	
Longview Lime Works (No. 2).	do	do	do	99.16	.75	Trace		5.15		100.06	
Franklin Quarry Co	Russellville	Franklin ..	J. C. Foster	97.00	1.40	.70		.80		100.00	
T. L. Fosick & Co.....	Sheffield	do	Chemist Watertown Arsenal (Nov. 20, 1895).				54.20	.50	42.61	Fe ₂ O ₃ 1.45 MgO ₂ 1.23	99.99
Do.....	Siluria.....	Shelby....	do	98.91	.58	.63		.10		100.22	
Shelby Iron Co.....	Shelby	do	C. F. Chandler, New York	99.13	.12			.23		Fe ₂ O ₃ Trace P ₂ O ₅ Trace	100.00
J. F. Landt.....	Stanley	Taladega ..	Albert Noble, Anniston, Ala.....	55.95	40.90	1.47		1.34			99.66

^a Includes also Al₂O₃ 0.21 per cent, organic matter, water, loss, and undetermined 0.31 per cent. Specific gravity, 2.84.

^b Insoluble in acids.

Analyses of lime from Alabama limestone.

Name of firm quarrying stone.	Location of quarry.		Name and address of analyst.	Substances determined.								Total.
	Town.	County.		Calcium carbonate, CaCO ₃ .	Magnesium carbonate, MgCO ₃ .	Oxides of iron and aluminum.	Calcium oxide, CaO.	Magnesium oxide, MgO.	Silica, SiO ₂ .			
Standard Lime Co	Fort Payne	Dekalb ...	Alfred D. Brainerd, Birmingham, Ala.	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per cent.</i>	<i>Per cent.</i>	
Longview Lime Works....	Longview	Shelby....	Wm. C. Stubbs, director Louisiana Sugar Experiment Station, New Orleans.	.....	*	0.26	98.44	.98	a 0.18	SO ₃ Trace. P ₂ O ₅ 0.01 CO ₂ 0.32	100.60	
Do.	do	do	A. L. Metz, chemist Louisiana State board of health.	1.53	0.56	.21	97.90	.....	a .37	.....	99.99	

^a Insoluble in acids.

^b Manganese dioxide, trace.

^c Includes 1.99 per cent as water, loss, and undetermined, P. 0.06 per cent and S. 0.2 per cent.

STONE.

ARIZONA.

Sandstone.—The following information was submitted by the Arizona Sandstone Company, operating quarries at Flagstaff, Coconino County. The crushing-strength tests were made at the navy-yard, Washington, District of Columbia, in June, 1889:

Crushing tests of sandstone from Flagstaff, Coconino County.

No.	Dimensions.	Cracked at—	Crushed at—
	<i>Inches.</i>	<i>Pounds.</i>	<i>Pounds.</i>
1	2.01 by 2.03 by 1.98	23,000	23,490
2	2.00 by 2.02 by 2.00	24,000	25,110
3	2.00 by 2.01 by 2.01	25,000	25,400
4	2.00 by 2.00 by 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, Coconino County.

	Per cent.
Silica (insoluble in acid), SiO_2	79.15
Soluble silica, SiO_2 .....	.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

ARKANSAS.

Granite.—The following table of tests gives results obtained at the mechanical laboratory of the Rensselaer Polytechnic Institute at Troy, New York. The testing machine used was a Tinius Olsen of 50,000 pounds capacity. The specimens were compressed between pieces of bookbinders' board three-sixteenths inch in thickness.

Results of tests of Arkansas syenites.

No.	Description of specimens.	County.	Area of surface.	Actual crushing load.	Pressure per square inch.	Reduced to correspond to pressure per square inch in two-inch cubes.	Ratio of absorption—1 to —.	Specific gravity at 60° F.
			<i>Sq. in.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>		
1	Light-colored elaeolite syenite, slightly decomposed.....	Saline ..	2.34	48,000	20,500	22,350	761	2.62
2	"Gray granite," a very light-colored elaeolite syenite	Pulaski ..	2.25	33,750	14,000	16,000	83	2.45
3	Brownish elaeolite porphyry, occurs in narrow dikes	do ..	1.42	30,000	21,000	24,000	161	2.32
4	"Light-blue granite" (syenite)	do ..	1.64	47,000	28,700	31,200	.....	.....
5	"Light-blue granite" (syenite), somewhat darker	do ..	1.67	22,800	21,500	26,820	.....	.....
6	"Light-blue granite" (syenite), still darker	do ..	1.57	35,050	22,900	26,745	1,673	2.64
7	"Medium-blue granite" (syenite)	do ..	1.50	45,500	30,000	34,150	.....	.....
8	"Dark-blue granite" (syenite porphyry)	do ..	1.57	40,800	27,900	32,630	4,530	2.60
	Mean of last five specimens.	do ..	.....	.....	26,000	30,740	.....	.....
	Average for "blue granite"	do ..	.....	.....	.....	.....	.....	.....

The following analysis of the stone, quarried by Mr. Mark Liles, at his quarries at Beaver, Carroll County, was made at the Navy Department at Washington, District of Columbia:

Analysis of limestone quarried at Beaver, Carroll County.

	Per cent.
Silica, SiO ₂	8.66
Oxides of iron and aluminum, Fe ₂ O ₃ and Al ₂ O ₃ ...	4.77
Calcium carbonate, CaCO ₃	48.48
Magnesium carbonate, MgCO ₃	33.58
Calcium sulphate, CaSO ₄.....	.42
Water alkalies, etc	4.09
Total	100.00

The following analysis of stone, quarried by the Crescent White Lime Works, at their quarries at Johnson, Carroll County, was made by Prof. G. L. Teller, of the Arkansas Industrial Institute, at Fayetteville:

Analysis of limestone quarried at Johnson, Carroll County.

	Per cent.
Material insoluble in acid.....	0.39
Oxides of iron and aluminum, Fe_2O_3 and Al_2O_3...	.17
Calcium carbonate, CaCO_3	99.34
Moisture .....	.10
Total	100.00

The crushing strength was found to be 15,500 pounds to the square inch, by Professor Martin, of the same institution.

CALIFORNIA.

Granite.—The following is a statement of results obtained at the Watertown Arsenal on granite from the quarries of the Rocky Point Granite Works at Exeter, Tulare County:

Tests of granite from Exeter, Tulare County.

[Shearing test.]

Number.	Shearing dimensions.	Shearing area.	Transverse fracture developed.	Shearing strength.	
				Total.	Per square inch.
	<i>Inches.</i>	<i>Square inches.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
302	4.04 by 6 by 2	48.48	42,500	117,300	2,419

Analysis of granite from Exeter, Tulare County.

	Per cent.
Silica, SiO_2	75.35
Oxide of iron, Fe_2O_3	3.94
Oxide of aluminum, Al_2O_3	13.69
Oxide of calcium, CaO	2.97
Oxide of magnesium, MgO} .....	.06
Oxide of sodium, Na_2O	1.14
Oxide of potassium, K_2O	2.85
Total.....	100.00

Transverse test of Exeter, Tulare County, granite.

[Ends supported 20 inches apart, loaded at the middle.]

Number.	Description.	Dimensions.		Ultimate strength.	
		Breadth.	Depth.	Total.	Modulus of rupture.
432	Light colored	<i>Inches.</i> 4.03	<i>Inches.</i> 6.07	<i>Pounds.</i> 9,170	<i>Pounds.</i> 1,853

Coefficient of expansion=0.00000461 per inch.

The following is a statement of mechanical tests made at the Watertown Arsenal by Maj. J. W. Reilly on the granite quarried by the Rocklin Granite Company at their quarries at Rocklin, Placer County:

Tests of granite quarried at Rocklin, Placer County.

[Tests by compression, granite cubes, pyramidal fractures.]

No. of test.	Marks.	Dimensions.			Sectional area.	First crack.	Ultimate strength.	
		Height.	Compressed surface.				Total.	Per sq. inch.
		<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Sq. inches.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
9819	No. 1	3.96	3.96	3.96	15.68	332,000	342,100	21,817
9820	No. 2	3.94	3.97	3.96	15.72	329,000	340,900	21,686
9821	No. 3	3.96	3.96	3.97	15.72	271,000	311,400	19,809

Marble.—The following analysis of Inyo marble, quarried by the Inyo Marble Company at their quarries in Inyo County, near Owens Lake, was made at the State University:

Analyses of the Inyo County marble.

	Per cent.
Carbon dioxide, CO ₂	47.353
Iron .....	.017
Calcium oxide, CaO	31.012
Magnesium oxide, MgO	21.791
Total	100.173

The following is from the State Mining Bureau report for 1890:

An analysis by Dr. W. D. Johnson and Mr. C. A. Ogden of a specimen of the purest white marble from the Inyo quarries shows that it is a typical and exceptionally pure dolomite. The composition of the sample analyzed was as follows:

	Per cent.
Carbonate of lime, CaCO_3	54.25
Carbonate of magnesium, MgCO_3	44.45
Iron and silica (clay).....	.60
Total.....	99.30

Crushing strength of the marble is given as 29,000 pounds per square inch.

The following data as to the composition and properties of the marble of Colton, San Bernardino County, were obtained by Prof. E. W. Hilgard, of the University of California:

Composition of Colton marble.

	Per cent.
Carbonate of calcium, CaCO_3	92.9
Carbonate of magnesium, MgCO_3	4.5
Black minerals.....	2.6
Total.....	100.0

The black minerals consist of biotite and pyrolusite. The minerals coloring the marble are very refractory to the action of the air and will produce no spotting under ordinary conditions. The stone is therefore a very durable one under any conditions in which marble is likely to be placed, whether in rough ashlar work or with polished face.

Prof. Frank Soule, of the University of California, found the crushing strength to be 9,350 pounds to the square inch.

Sandstone.—The following analysis, specific gravity, and absorption tests upon the sandstone quarried by the Colusa Stone Company at their quarries at Colusa, Colusa County, were made by Messrs. Thomas Price & Son, analytical chemists, of San Francisco, in May, 1896

Analysis of Colusa sandstone.

	Per cent.
Silica, SiO_2	85.99
Aluminum oxide, Al_2O_3	4.82
Iron oxide, Fe_2O_3	4.49
Calcium carbonate, CaCO_3	1.87
Magnesium oxide and alkalies .....	.76
Moisture .....	.69
Water of combination, organic matter, and loss..	1.38
	100.00

Specific gravity 2.558
 Water absorbed in 24 hours per cent.. 3.025

When heated to a red heat and plunged into water, the stone neither splinters nor cracks. It resists, without fusion, the temperature of a full white heat, not even the sharp edges of the stone being blunted. Plunged into water, after being subjected to a full white heat, the stone assumes a light-brown color.

We regard this as a very superior building stone.

The grains are small and uniform in size, thus forming a very compact rock, and one exceptionally well adapted for general use as a building material.

Three 1-inch cubes of the same stone were tested as to crushing strength by Mr. P. Noble, of the Pacific Rolling Mill Company, with the following results:

Crushing strength tests of Colusa sandstone.

	Pounds.
No. 1 broke at.	8,940
No. 2 broke at.	8,440
No. 3 broke at.	8,880

COLORADO.

Marble.—Mr. Henry Wood, analytical chemist, found the following results in an analysis of the marble from the quarries of the Denver Onyx and Marble Company, Beulah, Pueblo County, Colorado:

Analysis of marble from Beulah, Pueblo County.

	Per cent.
Carbonate of lime, CaCO_3	98.00
Magnesia, MgO} .....	.05
Iron (probably Fe_2O_3) .....	.04
Silica, SiO_2 .....	.06
Total	98.15

CONNECTICUT.

Granite.—The following tests of crushing strength were made by Mr. Ira H. Woolson, M. E., of Columbia University, New York City, upon 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, Middlesex County.

Crushing tests of granite from Middletown, Middlesex County; 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, Middlesex County; 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, Middlesex County.

COARSE-GRAINED GRANITE.

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

Test No.	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, Middlesex County--Continued.

FINE-GRAINED GRAY GRANITE.

[Mark: "South end B."]

Test No.	How tested.	Length or height.	Diameter or breadth.	Thickness.	Area.	First crack.	Stress in pounds compression, maximum.	
							On specimen.	Per square inch.
		<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Sq. in.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
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

The following tests of crushing strength of granite quarried by the Booth Brothers and Hurricane Isle Granite Company at its quarries at Waterford, New London County, were made by Mr. Ira H. Woolson, M. E., of Columbia University, New York City:

Crushing strength of granite from Waterford, New London County.

[Two-inch cubes tested.]

No.	Size.	Area.	First crack.	Crushed at.	Maximum per square inch.
	<i>Inches.</i>	<i>Sq. inches.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
1575	2.1 high by 2.00 by 1.98....	3.96	65,000	93,100	23,510
1576	2.008 high by 2.03 by 2.01..	4.08	92,600	97,600	23,921

The following analysis of the same granite was made by Messrs. Ricketts and Banks, of New York City:

Analysis of granite from Waterford, New London County.

	Per cent.
Silica, SiO_2	68.11
Alumina, Al_2O_3	14.28
Ferrous oxide, FeO	2.63
Lime, CaO	1.86
Magnesia, MgO} .....	.68
Sulphur .....	.34
Oxide of potassium, K_2O	5.46
Oxide of sodium, Na_2O	6.57
Total	99.93

The following gives the results of investigation of a trap rock at Meriden, New Haven County. 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 quarried at Meriden, New Haven County.

Test No.	Sectional area.	First crack.	Ultimate strength.	Per square inch.
	Sq. inches.	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 quarried at Meriden, New Haven County.

	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.

The following analysis of trap rock quarried by the Cooke Trap Rock Company at their quarry at Plainville, Hartford County, was made by Mr. Henry Souther, analyst, of Hartford:

Analysis of trap rock quarried at Plainville, Hartford County.

	Per cent.
Silica, SiO_2	50.26
Ferric oxide, Fe_2O_3	13.70
Aluminum oxide, Al_2O_3	15.16
Manganese oxide, MnO_2 .....	.48
Calcium oxide, CaO	10.68
Magnesium oxide, MgO	5.49
Water, H_2O	4.23
Total	100.00

Sandstone.—The following analysis of sandstone quarried by the New England Brown Stone Company at their quarry at Cromwell, Middlesex County, was made by Mr. F. W. Taylor:

Analysis of sandstone quarried at Cromwell, Middlesex County.

	Per cent.
Silica, SiO_2	70.84
Alumina, Al_2O_3	13.15
Ferric oxide, Fe_2O_3	2.48
Calcium oxide, CaO	3.09
Magnesium oxide, MgO	Trace.
Manganese oxide .....	.70
Potassium oxide, K_2O	3.30
Sodium oxide, Na_2O	5.43
Carbon dioxide and loss	1.01
Total	100.00

The following table gives the results of a number of tests of Con-

Physical tests of sandstone

Name of firm quarrying stone.	Location of quarry.		Name and address of expert conducting tests.
	Town.	County.	
Brainerd, Shaler & Hall Quarry Co.	Portland.....	Middlesex..	Prof. Ira H. Woolson, School of Mines, Columbia University, New York City.
Do	do	do	do
Do	do	do	do
Do	do	do	do
Do a.....	do	do	Maj. J. W. Beilly, Watertown Arsenal.
Do b.....	do	do	do
Do c.....	do	do	do
Do d.....	do	do	do
Middlesex Quarry Co.	do	do	Prof. Ira H. Woolson, School of Mines, Columbia University, New York City.
Do	do	do	do
Do	do	do	do
Do	do	do	do
New England Brown Stone Co.	do	do	do
Do	do	do	do
Do	do	do	do
Do	do	do	do
Portland Quarries.....	do	do	Watertown Arsenal
Do	Middletown	do	General Gillmore, Chief of Engineers, report, 1875.
New England Brown Stone Co.	Crosswell	do	Watertown Arsenal

a First quality.

b Second quality.

neetient sandstones:

quarried in Connecticut.

Compression tests.									
No. of test.	How tested.	Grain.	Dimensions.			Sectional area.	First crack.	Ultimate strength.	
			Height.	Compressed surface.				Total.	Per square inch.
			<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
1637	Bed.....	Moderately coarse.	3.017	3.004	3.007	9.033	107,600	110,400	12,221
1658	.....do.....	Fine.....	2.977	3.000	3.011	9.633	98,200	98,200	10,871
1659	.....do.....	.....do.....	3.007	3.022	3.003	9.675	112,400	112,400	12,385
1660	.....do.....	Very coarse	3.011	3.014	3.005	9.657	102,300	102,400	11,306
7330	.....	.....	2.50	2.50	2.45	6.13	84,800	85,700	12,980
7331	.....	.....	2.50	2.48	2.47	6.13	81,700	81,700	12,320
7332	.....	.....	2.98	3.00	2.95	8.85	123,200	123,200	13,920
7333	.....	.....	2.95	2.98	2.97	8.85	122,000	122,950	13,920
7334	.....	.....	2.52	2.55	2.50	6.45	63,850	63,850	9,900
7335	.....	.....	2.48	2.48	2.52	6.35	58,340	58,340	9,330
1653	Bed.....	Fine.....	3.017	3.017	3.019	9.108	100,000	105,700	11,605
1654	.....do.....	.....do.....	2.982	3.005	2.980	8.981	94,000	94,000	10,466
1655	.....do.....	.....do.....	3.000	3.010	2.919	9.087	75,200	87,500	9,629
1656	.....do.....	.....do.....	3.006	2.993	3.015	8.993	111,000	112,400	12,498
1649	.....do.....	.....do.....	3.019	3.020	2.965	9.044	111,800	117,100	12,947
1650	.....do.....	.....do.....	3.037	3.010	3.035	9.135	110,000	110,000	12,041
1651	.....do.....	.....do.....	3.021	3.043	3.034	9.232	117,100	117,100	12,947
1652	.....do.....	.....do.....	3.026	3.035	3.048	9.250	92,400	98,000	10,594
.....	.....	.....	.....	.....	.....	.....	.....	.....	12,580
.....	.....	.....	.....	.....	.....	.....	.....	.....	8,250
.....	.....	.....	.....	.....	.....	.....	.....	.....	16,890

e Third quality.

d Bridge quality.

Physical tests of sandstone quarried

Name of firm quarrying stone.	Location of quarry.		Name and address of expert conducting tests.
	Town.	County.	
Brainerd, Shaler & Hall Quarry Co.	Portland.....	Middlesex..	Prof. Ira H. Woolson, School of Mines, Columbia University, New York City.
Do	do	do	do
Do	do	do	do
Do	do	do	do
Middlesex Quarry Co.....	do	do	do
Do	do	do	do
Do	do	do	do
Do	do	do	do
New England Brown Stone Co.	do	do	do
Do	do	do	do
Portland Quarries.....	do	do	Watertown Arsenal.....
Do	Middletown	do	General Gillmore, Chief of Engineers, report, 1875.
New England Brown Stone Co.	Cromwell	do	Watertown Arsenal.....

in Connecticut—Continued.

Transverse tests.						Number of specimens tested.	Specific gravity.	Weight per cubic foot.	Ratio of absorption.
No. of test.	Distance between supports.	Dimensions.		Ultimate strength.					
		Breadth.	Depth.	Total.	Modulus of rupture.				
	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Pounds.</i>				<i>Pounds.</i>	
1665	19	4.02	6.01	9,500	1,864				
1666	19	3.99	5.98	9,300	1,837				
1667	19	4.01	6.00	10,500	2,073				
1668	19	4.00	6.01	9,800	1,933				
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				
1673	19	4.01	5.99	9,900	1,961				
1674	19	4.13	6.04	10,400	1,977				
						4	2.55	146.9	1-40
						2 {	2.63	148.5	1-40
							2.36		
						2 {	2.63	156.9	1-40
							2.50		

Limestone.—The following analyses of limestone quarried by the Canaan Lime Company at their quarries at Canaan, Litchfield County, and of the lime made from it were made by Mr. J. S. Adam, chemist:

Analysis of limestone quarried at Canaan, Litchfield County.

	Per cent.
Calcium carbonate, CaCO_3	54.40
Magnesium carbonate, MgCO_3	45.12
Oxides of iron and aluminum .....	.25
Silica, SiO_2 .....	.08
Total	99.85

Analysis of lime from limestone quarried at Canaan, Litchfield County.

	Per cent.
Lime, CaO	56.57
Magnesia, MgO	42.56
Silica and alumina, SiO_2 and Al_2O_3 .....	.42
Carbon dioxide and water .....	.10
Total	99.65

The following is an analysis of limestone quarried by Messrs. Canfield Brothers at their quarries at East Canaan, Litchfield County, made at the Connecticut Agricultural Experiment Station:

Analysis of limestone quarried at East Canaan, Litchfield County.

	Per cent.
Matter insoluble in acid	0.48
Oxides of iron and aluminum .....	.20
Lime, CaO	31.31
Magnesia, MgO	21.03
Carbon dioxide, CO_2	46.98
Total	100.00

DELAWARE.

Granite.—The following tests and analysis were made by Messrs. Booth, Garrett, and Blair, of Philadelphia, on the gneiss quarried by the Brandywine Granite Company, of Wilmington, Delaware, at their quarries at Rockford, Newcastle County.

Analysis and tests of granite from Rockford, Newcastle County.

	Per cent.
Loss on ignition, i. e., organic matter and moisture.....	0.30
Silica, SiO_2	67.98
Alumina, Al_2O_3	16.14
Ferrous oxide, FeO	4.39
Lime, CaO	5.89
Magnesia, MgO	53
Oxide of sodium, Na_2O	4.32
Oxide of potassium, K_2O}.....	.45
Total.....	100.00

Specific gravity = 2.77.

Crushing test: On natural bed No. 1, 2 by 2 inches equals 4 square inches, at 100,300 pounds, equals 25,075 pounds per square inch. Across natural bed No. 2, 2 by 2 inches equals 4 square inches, at 99,000 pounds, equals 24,750 pounds per square inch.

Average: 24,913 pounds per square inch.

Absorption of water: Weight after drying twenty-four hours at 212° F., 1.20 pounds. Weight after immersing twenty-four hours in distilled water, 1.20 pounds. Water absorbed, 0.0 pounds or 0.0 per cent.

GEORGIA.

Granite.—The following results of crushing strength test were obtained by Maj. J. W. Reilly at the Watertown Arsenal upon granite, quarried by Venable Brothers at their quarries at Stone Mountain and Lithonia, Dekalb County:

Tests of granite quarried at Stone Mountain, Dekalb County.

No.	Pounds per square inch.	Position.
1.....	25,630	On bed.
2.....	28,130	On bed.

Tests of granite quarried at Lithonia, Dekalb County.

No.	Pounds per square inch.	Position.
1.....	30,320	On bed.
2.....	28,290	On bed.
3.....	28,250	On bed.

Marble.—The following tests, taken from Bulletin No. 1 of the Geological Survey of Georgia, 1894, were made at the University of Tennessee on a Tinius Olsen testing machine, capacity 20,000 pounds, upon inch cubes placed between pieces of dense cardboard one-sixteenth inch in thickness. The specimens were furnished by the Georgia Marble Company and the Southern Marble Company from their various quarries near Tate, Pickens County. The absorption tests were also made at the University of Tennessee.

Crushing tests of Georgia marble.¹

Name of quarry.	Name of firm quarrying stone.	Compressed surface.	Position.	Actual crushing load.	Compressive strength per square inch.	Reduced to correspond to pressure per square inch on 2-inch cubes, ^a	Specific gravity.	Weight per cubic foot.
		<i>Inches.</i>		<i>Pounds.</i>	<i>Pounds.</i>	<i>Lbs. per sq. in.</i>		
Kennesaw, No. 1.....	Georgia Marble Co.	0.99 by 0.99	Bed.	10,000	510,204	12,244		
Kennesaw, No. 2.....	do	1.00 by 1.00	Bed.	11,400	211,400	13,680	2.717	169.8
Kennesaw, No. 3.....	do	1.00 by 1.00	Bed.	10,672	210,672	12,806		
Creole, No. 1.....	do	1.00 by 1.00	Bed.	13,900	213,900	16,680		
Creole, No. 2.....	do	1.00 by 1.00	Bed.	13,100	213,100	15,700	2.763	172.6
Creole, No. 3.....	do	1.00 by 1.00	Bed.	13,200	13,200	15,840		
Etowah, No. 1.....	do	1.00 by 1.00	Bed.	13,200	13,200	15,840		
Etowah, No. 2.....	do	.99 by .99	Bed.	12,000	12,244	14,002	2.707	169.1
Etowah, No. 3.....	do	.99 by .98	Bed.	12,300	12,540	15,048		
Southern, No. 1.....	Southern Marble Co.	.99 by 1.00	Bed.	11,300	11,414	13,606		
Southern, No. 2.....	do	.99 by 1.00	Bed.	10,900	11,010	13,212	2.734	171.8
Southern, No. 3.....	do	.98 by 1.00	Bed.	10,800	11,020	13,224		

^a Gen. Q. A. Gillmore, in his report on the compressive strength of building stones of the United States, Appendix II, Annual Report of the Chief of Engineers for 1875, determined a general formula for converting the crushing strength of different cubes into each other. In applying this formula for 1 and 2 inch cubes, it is found that the crushing weight of the smaller cube should be increased by approximately one-fifth of itself, in order to compare correctly the strength of the two cubes.

^b Cracked on edge before bursting.

^c Burst suddenly.

^d Burst with explosion.

¹ The Survey is under obligations to Prof. Charles Ferris, of the engineering department of the University of Tennessee, for valuable aid rendered in making the crushing and absorption tests.

Absorption tests of Georgia marble.

Name of firm, quarrying stone.	Name of quarry.	Weight, after drying for 24 hours at 212° F.	Weight, after re- maining in water for 72 hours at about 60° F.	Approx- imate per- centage of absorption.
		<i>Grams.</i>	<i>Grams.</i>	<i>Per cent.</i>
Georgia Marble Co	Kennesaw ...	45.160	45.200	0.008
Do	Creole	44.320	44.335	.004
Do	Etowah	42.215	42.240	.005
Southern Marble Co	No. 1	46.170	46.200	.006
Do	No. 2	44.440	44.475	.008

The following artificial weathering tests taken from Bulletin No. 1 of the Geological Survey of Georgia, 1894, were made by W. H. Emerson, Ph. D., upon specimens furnished by the Georgia Marble Company from their quarries near Tate, Pickens County. The specimens were suspended for several days in an atmosphere of hydrochloric, sulphurous and carbonic acids.

Weathering tests of marble from Pickens County.

No.		Original weight.	Final weight.	Loss.
		<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
1	Polished	45.0868	44.9337	.1531
1	Unpolished	45.9492	45.7793	.1699
3	Do	44.2569	44.1240	.1329
6	Do	42.1369	41.9943	.1426

It is noticeable that the unpolished cube of No. 1 was dissolved with considerable more readiness than the polished.

The following chemical analyses were also made by Dr. Emerson. The samples were taken from various localities in Georgia, as indicated by the explanatory notes appended.

Chemical analyses of Georgia marbles.

No.	Calcium oxide.	Magnesium oxide.	Ferric oxide and alumina.	Insoluble siliceous matter.	Loss on ignition.	Total.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
1	54.06	0.90	0.10	2.12	42.86	100.04
2	32.73	19.37	.35	0.73	46.58	99.76
3	55.00	1.12	.15	.35	44.16	100.76
4	31.53	21.30	.24	.10	47.26	100.43
5	31.61	21.06	.78	1.01	46.49	100.95
6	54.41	.75	.32	1.62	43.13	100.23
7	54.67	1.01	.42	.76	43.49	100.35
8	52.77	.82	3.28	1.43	41.85	100.15
9	24.07	17.24	.43	21.76	37.08	100.58
10	30.42	19.86	.91	4.23	(a)	.....
11	31.89	19.64	.74	1.73	(a)	.....

a Undetermined.

1. A coarsely crystalline, white marble, from the Cherokee quarry (Georgia Marble Company), Pickens County.
2. A white, fine-grained marble, from Mr. J. P. Harrison's quarry, 2 miles east of Jasper.
3. A coarse-grained, black-and-white mottled marble, "Creole," of the Georgia quarries.
4. A fine-grained, gray marble, from the Dickey property.
5. A fine-grained, bluish-gray marble, from the Holt property.
6. A coarse-grained flesh-colored marble, "Etowah," of the Georgia quarries.
7. A coarse-grained, gray marble, from the Eslinger farm.
8. A coarse-grained, brown marble, from the Haskins farm.
9. A fine-grained, light-gray marble, from the White property.
10. A fine-grained, black marble from Six Mile Station.
11. A fine-grained, white marble, from Fannin County.

The following analysis of marble quarried by the Southern Marble Company at their quarries at Marblehill, Pickens County, was made by L. P. Kinnicutt, Ph. D., of the Institute of Technology, Worcester, Massachusetts:

Analysis of marble from Marblehill, Pickens County.

	<i>Per cent.</i>
Carbonate of calcium, CaCO_3	98.96
Aluminum and iron oxides, Al_2O_3 and Fe_2O_3.....	.22
Insoluble residue.....	.61
Loss and undetermined.....	.08
Total.....	99.87

The following is an analysis of Pickens County marble, quarried by the Georgia Marble Company at their quarries near Tate, Pickens County, made by Mr. John C. Jackson, of Chicago:

Analysis of Pickens County marble.

	Per cent.
Calcium carbonate, CaCO_3	97.32
Magnesium carbonate, MgCO_3	1.60
Silica, SiO_2 .....	.62
Iron protoxide, FeO} .....	.26
Alumina, Al_2O_3 .....	.25
Total	100.05

The following tests, by compression, of the strength of three cubes of Georgia marble, quarried by the Georgia Marble Company at their quarries near Tate, Pickens County, made in 1886 by Capt. Marcus W. Lyon, United States Army, with the testing machine at Watertown Arsenal, Massachusetts, serve to indicate the crushing strength of this marble:

Mechanical tests of Georgia marble.

Test No.	Marks.	Dimensions.		Sectional area.	Ultimate strength.	
		Height.	Compressed surface.		Total pounds.	Pounds per square inch.
		<i>Inches.</i>	<i>Inches.</i>	<i>Sq. Inch.</i>		
4337	Cherokee ..	6.04	6.01 by 6.00	36.06	395,800	10,976
4338	Creole	6.06	6.00 by 5.99	36.94	434,100	12,078
4339	Etowah	6.03	6.03 by 6.01	36.12	384,400	10,642

Limestone.—The following analyses of lime and limestone, quarried by the A. C. Ladd Lime Works at their quarries at Bartow, Jefferson County, were made by Mr. N. P. Pratt, formerly State mineralogist:

Analysis of lime from Bartow, Jefferson County.

	Per cent.
Lime, CaO	34.070
Magnesia, MgO	55.736
Alumina and iron oxide	1.236
Silica, SiO_2	7.252
Moisture	1.622
Total	99.916

Analysis of limestone from Bartow, Jefferson County.

	Per cent.
Calcium carbonate, CaCO_3	56.02
Magnesium carbonate, MgCO_3	38.43
Alumina and iron oxide	1.50
Silica, SiO_2	1.94
Moisture	0.00
Total	97.89

Slate.—The following analysis of slate, quarried by the Georgia Slate Company at their quarries at Rockmart, Polk County, was made by Messrs. J. W. Slocum and H. H. Van Deventer, chemists, of Knoxville, Tennessee:

Analysis of Rockmart slate.

	Per cent.
Silica, SiO_2	58.20
Alumina, Al_2O_3	18.83
Protoxide of iron, FeO	5.78
Lime, CaO	4.35
Magnesia, MgO	3.51
Potassium oxide, K_2O	2.51
Sodium oxide, Na_2O} .....	.60
Carbon, C} .....	.82
Carbonic acid, CO_2 .....	.00
Sulphur, S} .....	.49
Water, H_2O	4.07
Titanic acid, TiO_2 .....	.10
Lithia, Li_2O} .....	.02
Oxide of manganese	Trace.
Total	99.97

ILLINOIS.

Limestone.—The following is a table of analyses of limestone quarried in Illinois:

Analyses of limestone quarried in Illinois.

Name of firm quarrying stone.	Location of quarry.		Name and address of analyst	Substances determined.								
	Town.	County.		Calcium carbonate, CaCO_3 .	Magnesium carbonate, MgCO_3 .	Oxides of iron and aluminum.	Silica, SiO_2 .	Insoluble matter.	Water loss.	Moisture, organic matter, and alkalis.	Total.	
Chicago Union Lime Works Co.	Chicago	Cook	J. Blodget Britton, Ironmasters' Laboratory, Warrenton, Va.	Per ct. 52.76	Per ct. 45.04	Per ct. 1.48	Per ct. .	Per ct. 0.21	Per ct. 0.51	Per ct. .	Per ct. 100.06	
Marble Head Lime Co.	Marble Head	Adams	N. Gray Bartlett, 94 23d st., Chicago, Ill.	56.62	.82	2.18	6.47	.....	.....	0.91	100.00
F. W. Menke Stone and Lime Co.	Quincy	.....do	C. G. Hopkins, University of Illinois.	92.77	6.75	.27	.....	.27	.....	.....	100.16
Stearns Stone and Lime Co.	Chicago	Cook	T. C. Hopkins, State College, Pa.	52.75	44.28	.55	.....	.60	.....	.....	98.18
Artesian Stone and Lime Co.	.....do	.....do	.....do	53.79	42.34	1.04	.....	1.28	.....	.....	98.36
Lumpy layer	.....do	.....do	.....do	52.07	42.18	1.78	.....	4.00	.....	.....	100.03
Union Lime Co.	.....do	.....do	.....do	54.99	44.04	.18	.....	.87	.....	.....	100.48
Blue Island quarry	.....do	.....do	.....do	53.39	19.40	2.04	.34	54.15	.....	.....	99.32
Insoluble portion of Blue Island quarry stone.	.....do	.....do	.....do	.....	.....	15.79	73.35	.....	.....	a 0.58	.....
Stony Island avenue quarry	.....do	.....do	.....do	52.08	37.54	.....	.....	.....	.....	.....	89.62

a Includes 1.03 per cent of magnesia, MgO .

The following analysis was made by Prof. S. E. Swartz, Shurtleff College, Upper Alton, Illinois, of lime made from limestone quarried by Mr. John Armstrong at his quarries at Alton, Madison County:

Analysis of lime from limestone quarried at Alton, Madison County.

	Per cent.
Calcium oxide, CaO	97.72
Ferrous oxide, FeO .....	.20
Alumina, Al ₂ O ₃	1.10
Silica, SiO ₂	1.01
Magnesia, MgO	None.
Total	100.03

The following is a partial analysis of the stone quarried by the Kankakee Stone and Lime Company at their quarries at Kankakee, Kankakee County, made by Mr. C. S. Robinson, chemist of Illinois Steel Company:

Analysis of limestone from Kankakee, Kankakee County.

	Per cent.
Silica, SiO ₂	3.00
Oxides of iron and aluminum, Fe ₂ O ₃ and Al ₂ O ₃ ..	2.50
Calcium oxide, CaO	30.45
Magnesium oxide, MgO	20.50
Phosphorus .....	.006

The following data in regard to the same stone were secured by Prof. C. W. Rolfe, of the Illinois State University, at Champaign:

Weight per cubic foot, 165.75 pounds; specific gravity, 2.65; crushing strength, 13,544 pounds to the square inch.

INDIANA.

Sandstone.—The following results of crushing strength test and chemical analysis of sandstone quarried by Messrs. Guyer and Burchby at Riverside, Fountain County, were obtained by Prof. W. S. Blatchley, State geologist:

Crushing tests of Riverside sandstone.

No.	Sample.	Pounds per square inch.
1	Gray	6,000
2	Blue	6,090

Analysis of Riverside sandstone.

	Per cent.
Insoluble residue, SiO_2	93.16
Alumina, Al_2O_3	1.60
Ferrie oxide, Fe_2O_3	2.60
Lime, CaO}.....	.13
Total	97.58

Analyses of sandstone quarried in Indiana.

380

MINERAL RESOURCES.

Name of firm quarrying stone.	Location of quarry.		Name of analyst.	Substances determined.						
	Town.	County.		Silica, SiO ₂ .	Alu- mina, Al ₂ O ₃ .	Ferrie oxide, Fe ₂ O ₃ .	Cal- cium oxide, CaO.	Carbon dioxide, CO ₂ .		Total.
				<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i> MgO 1.41 H ₂ O 3.29	<i>Per ct.</i>
	Portland a	Jay		91.18	2.14	1.12	0.86			100.00
J. B. Lynne & Sons b	Mansfield	Parke	W. A. Noyes, Rose Polytechnic.	92.16		6.29	.65		Alkalies 0.09	98.56
	St. Anthony	Dubois	do	88.41	.63	8.40	.13	0.10		97.67
	Bloomfield	Greene	do	85.29	.19	11.83	.06	.05		97.42
	Greenhill	Warren	do	98.73	.28	.36	.03	.02		99.42
	Hillsboro	Fountain	do	91.65	.56	6.60	.12	.10		99.03
	Judson	Parke	do	92.21	.51	4.91	.12	.10		98.85
	Fountain	Fountain	do	91.66	.60	6.44	.05	.04		98.79
Williamsport Stone Co.	Williamsport	Warren	do	98.57	.65	.65	.02	.02		99.31
F. S. Pauline & Co	Cannelton	Perry	do	96.18	.54	1.56	.15			98.43

a Professor Kramer, of Cincinnati, Ohio, gives crushing strength of this stone as 6,825 pounds per square inch.

b Crushing strength given as 3,000 pounds per square inch and ratio of absorption 1-13.

c Includes silica and insoluble silicates.

d Insoluble in hydrochloric acid.

e Calcium carbonate.

Limestone.—The following table gives the results of a number of analyses of limestone quarried in Indiana:

Analyses of limestone quarried in Indiana.

Name of firm quarrying stone.	Location of quarry.		Name and address of analyst.	Substances determined.													
	Town.	County.		Calcium carbonate, CaCO ₃ .	Magnesium carbonate, MgCO ₃ .	Oxides of iron and aluminum.	Silica, SiO ₂ .	Ferrie oxide, Fe ₂ O ₃ .	Alumina, Al ₂ O ₃ .	Calcium oxide, CaO.	Magnesium oxide, MgO.	Water and loss at 212° F.	Carbon dioxide, CO ₂ .	Loss and undetermined.	Sulphuric anhydride, SO ₃ .	Total.	
Acme Bedford Stone Co.	Clear Creek.	Monroe.....	W. S. Blatchley, State geologist, Rose Polytechnic Institute.	Per ct. 97.39	P. ct. 0.78	P. ct. 0.13	P. ct. 0.84	P. ct.	P. ct.	Per ct. 60.10	P. ct.	P. ct.	Per ct.	P. ct.	P. ct.	Per cent. 99.24	
Bedford Quarries Co.	Bedford	Lawrence...	F. W. Clarke, chief chemist U. S. Geological Survey.	97.26			1.09	0.49			0.37	0.19				100.00	
Bedford Portland Cement Co.							.89	3.25	0.38	54.48	.56		43.40			99.76	
No. 1	do	do	Prof. A. W. Smith, Case School of Applied Science, Cleveland, Ohio.					.87	.15	.94	54.68	.32		43.44		99.78	
No. 2	do	do	do													99.90	
Bedford Indiana Stone Co.	do	do	do	98.27	.84	.15	a .64										
Hunter Valley Quarry			do	98.11	.92	.16	a .88									100.05	
Romona Quarry	Romona	Owen	do	97.90	.65	.18	a1.26									99.99	
Twin Creek Quarry	Salem	Washington	do	98.16	.97	.15	a .76									100.04	
Hoosier Quarry (buff)			do	98.20	.29		a .63	.39								99.61	
Salem Quarry			do	96.04	.72	1.00	a1.13			a0.15		.19					
Mauckport Quarry	Mauckport	Harrison	do	98.09			a .31	.18	.14	a0.40		.12					
Big Creek Quarry			do	93.80	4.01		a .15	.64					1.00			99.69	
a Insoluble in acid.			b Including 0.13 of ferrous oxide.			c Sodium oxide.			d Potassium and sodium oxides.								

a Insoluble in acid.

b Including 0.13 of ferrous oxide.

c Sodium oxide.

d Potassium and sodium oxides.

Name of firm quarrying stone.	Location of quarry.		Name and address of analyst.	Substances determined.													
	Town.	County.		Calcium carbonate, CaCO_3	Magnesium carbonate, MgCO_3	Oxide of iron and aluminum.	Silica, SiO_2	Ferrous oxide, FeO	Alumina, Al_2O_3	Calcium oxide, CaO	Magnesium oxide, MgO	Water and loss at 212°F .	Carbon dioxide, CO_2	Loss and undetermined.	Sulphuric anhydride, SO_3	Total.	
Defenbaugh & Smith:				Per cent.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	Per cent.	P. ct.	P. ct.	Per cent.	P. ct.	P. ct.	Per cent.	
No. 1.....	Kokomo.....	HowaM.....	Grasselli Chemical Co.....	98.66				.24	Trace	.43		Trace				99.33	
No. 2.....	do.....	do.....	do.....	97.05				1.62	.16	.60		.36			Trace	99.79	
Baltes Land, Stone, and Oil Co.:																	
Top rock.....	Montpelier.....	Blackford.....	S. S. Gorby, State geologist.			4.70	2.75			42.92	3.88	.95	41.20	2.41	0.79	100.00	
Intermediate rock.....	do.....	do.....	do.....			5.25	2.68			42.55	4.40	1.25	39.10	3.68	1.09	100.00	
Bottom rock.....	do.....	do.....	do.....			5.17	2.43			43.01	4.19	1.00	41.52	1.78	.88	100.00	
Huntington White Lime Co.	Huntington.....	Huntington.....	G. M. Levette, Indianapolis, Ind.			4.70	2.75			42.92	4.41	.95	41.20	1.82	1.25	100.00	
Indiana Macadam and Construction Co.	Rensselaer.....	White.....	W. E. Stone, professor of chemistry, Purdue University.	56.28	43.26	.14	4.33									100.01	
J. A. Derbyshire.....	Laurel.....	Franklin.....	Prof. W. A. Noyes, Rose Polytechnic Institute, Terre Haute, Ind.	43.67	20.60	11.01	21.51			61.55		1.39				99.73	
Romona Oolitic Stone Co.	Romona.....	Owen.....	do.....			.18	61.26			54.82	.31		43.49			100.06	
Peru Stone and Lime Co.	Peru.....	Miami.....	J. N. Hurtz, Indianapolis, Ind.	52.90	38.94		4.05	1.20	1.25				2.63			100.97	
Caspary Stone Co.....	Kenneth.....	Cass.....	S. S. Gorby, State geologist.	93.48		2.67	1.33				1.16	1.57		.39		100.00	
Twin Creek Stone and Land Co.	Salem.....	Washington.....	Prof. W. A. Noyes, Rose Polytechnic Institute.			.15	6.76			54.97	.46		43.68			100.02	

a Includes 0.25 per cent insoluble in acids.

b Potassium and sodium oxides.

c Insoluble in acid.

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

Physical characteristics of Bedford oölitic limestone.

Operators.	Locality.	County.	Crush- ing strength per square inch.	Num- ber of speci- mens tested.	Spe- cific grav- ity.	Weight per cubic foot.	Ratio of ab- sorp- tion.	Authority.
			<i>Pounds.</i>			<i>Pounds.</i>		
G. K. Perry	Ellettsville ..	Monroe ..	10,000	4			1-31	Rose Polytech- nic Institute.
Matthews Bros.	do ..	do ..	12,500			142.2	1-28	General GIB- more.
Indiana Steam Stone Works.	Stinesville ..	do ..	5,600	3			1-17	Rose Polytech- nic Institute.
Hunter Valley Stone Co.	Bloomington ..	do ..	4,100	3			1-14	Do.
Hunter Brothers Stone Co.	do ..	do ..	5,700	3	2.46	153.7	1-19	Do.
Crescent Stone Co.	do ..	do ..	5,700	3			1-15	Do.
Romona Oölitic Stone Co.	Romona	Owen	9,100	4	2.48	135	1-39	Do.
Bedford, Ind., Stone Co.	Bedford ..	Lawrence	5,000	3	2.47	154.4	1-23	Do.
The Chicago and Bedford Stone Co.	do ..	do ..	8,000	3			1-31	Do.
Bedford Quar- ries Co.	do ..	do ..	4,450	4			1-15	Do.
Dark Hollow Stone Co.	Bedford ..	Washing- ton.	6,625			142.9	1-19	General GIB- more.
Twin Creek Stone Co.	Salem ..	do ..	9,900	3	2.51	156.9	1-31	Rose Polytech- nic Institute.

IOWA.

Limestone.—The following analysis of limestone quarried by Messrs. L. B. Stuart & Co. at their quarry at Monmouth, Jackson County, was made by Prof. Samuel Calvin, State geologist.

Analysis of limestone quarried at Monmouth, Jackson County.

	Per cent.
Insoluble silicates (sand)	0.42
Ferrie oxide, Fe ₂ O ₃ .....	.53
Calcium carbonate, CaCO ₃	57.54
Magnesium carbonate, MgCO ₃	41.51
Total	100.00

The following physical data were obtained by Messrs. R. H. Hollembeak and W. M. Jones, of Iowa State Agricultural College, upon limestone from the quarries of the Le Grande Quarry Company, of Le Grande, Marshall County.

Physical tests of Le Grande limestone.

Quarry.	Crushing tests.				Absorption in 180 hours.			
	No.	Strength per square inch.	No.	Strength per square inch.	No.	Per cent.	No.	Per cent.
		<i>Pounds.</i>		<i>Pounds.</i>				
North quarry	11	(a)	12	(a)	3	1.79	2	0.77
Do					7	1.32		
South quarry	15	(a)	26	15,940				
West quarry	28	9,773	31	15,940	30	1.83	29	1.70
North quarry	1	9,290			25	0.54		
South quarry	36	10,375	35	10,409	13	5.10		
Do	37	10,930						
West quarry	16	15,309			19	3.92	17	3.03
Do					18	4.70		
North quarry	a 10	10,825	9	11,055	8	4.53	49	5.55
South quarry	39	(a)	42	(a)	41	1.50	40	2.00
North quarry	27	(b)	24	(b)	519	2.03		
Timber Creek quarry ..	33	8,712	34	8,383	32	3.20	45	5.35
North quarry	4	13,450	5	14,970	20	2.75	21	4.05
Do	6	10,209						
South quarry	22	12,740	23	14,250	38	2.62	44	2.21
Do	43	13,259			46	2.96		

No.	Locality.	Kind of stone.	Crushing strength per square inch.		Percentage of absorption in 192 hours.	Percentage of loss in weight, freezing 20 times.	Sp. gr.
			Before freezing.	After freezing 20 times.			
			<i>Pounds.</i>	<i>Pounds.</i>	<i>Per ct.</i>	<i>Per ct.</i>	
6J	Le Grande..	Buff fossiliferous limestone.	6,640	5,670	5.96	0.03	2.288
5J	.....do	"Iowa marble," buff limestone, veined.	12,100	12,625	3.61	.07	2.454
3J	.....do	"Caen stone," buff magnesian limestone.	6,600	(a)	6.26	4.05	2.304
4J	.....do	Hard blue limestone ..	23,985	26,200	.83	.06	2.451
2J	.....do	Gray siliceous limestone..	7,440	6,380	4.21	.03	2.396
1A	Stone City..	Warm, gray dolomitic limestone.	3,375	4,185	9.77	.18	2.029
2A	.....do .....	.....do	3,500	5,000	10.00	.10	2.072
3A	.....do .....	.....do	9,040	6,360	6.96	.02	2.158

a Not broken because so badly disintegrated.

b (f).

Sandstone.—The following tests were made by Messrs. R. H. Hollembeck and W. M. Jones, of Iowa State Agricultural College, upon blue-gray calcareous sandstone quarried at La Grande:

Crushing strength.		Percentage of absorption in 192 hours.	Percentage of loss after freezing 30 times.	Specific gravity.
Before freezing.	After freezing 20 times.			
<i>Lbs. per sq. in.</i> 6,805	Too badly disintegrated..	<i>Per cent.</i> 4.66	<i>Per cent.</i> 1.85	2.029

KANSAS.

Sandstone.—The following table gives the results of a number of analyses of sandstone quarried in Kansas:

Tests and analyses of sandstone quarried in Kansas.

Name of firm quarrying stone.	Location of quarry.		Name and address of analyst.	Crushing strength per square inch.	Weight per cubic foot.	Specific gravity.	Ratio of absorption.		
	Town.	County.							
James McGinty .	Valley Falls.	Jefferson.	Dr. S. W. Williston, Lawrence, Kans.	<i>Pounds.</i> 1,612	<i>Pounds.</i> 152.3	2.44	0.12		
Ezekiel Marshall .	.....do.....	.....do.....	.....do.....	8,657	133.2	2.45	.61		
Name of firm quarrying stone.	Location of quarry.		Name and address of analyst.	Analyses.					
	Town.	County.		Insoluble matter.	Oxides of iron and aluminum.	Calcium carbonate CaCO ₃ .	Magnesium carbonate MgCO ₃ .	Sulphate.	Total.
James McGinty .	Valley Falls.	Jefferson.	Dr. S. W. Williston, Lawrence, Kans.	<i>Pr. ct.</i> 94.35	<i>Pr. ct.</i> 2.35	<i>Pr. ct.</i> 1.14	<i>Pr. ct.</i> 1.01	<i>Pr. ct.</i> 0.42	<i>Pr. ct.</i> 99.27
Ezekiel Marshall .	.....do.....	.....do.....	.....do.....	97.71	1.31	.21	.54	.23	100.00

a Average of 5 blocks.

Limestone.—The following table gives the results of a number of analyses of limestone quarried in Kansas:

Tests and analyses of limestone quarried in Kansas.

Name of firm quarrying stone.	Location of quarry.		Name and address of analyst.	Crushing strength.	Weight per cubic foot.	Specific gravity.	Ratio of absorption.	Substances determined by analyses.					
	Town.	County.						Insoluble matter.	Oxides of iron and aluminum.	Calcium carbonate, CaCO ₃ .	Magnesium carbonate, MgCO ₃ .	Sulphates.	Total.
				Pounds.	Pounds.		Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per cent.
H. Hedderman..	Cambridge..	Cowley	Dr. S. W. Williston, Lawrence, Kans.	12,567	164.5	2.63	0.01	3.34	1.69	93.98	0.94	.....	99.95
I. Kuhn & Co..	Marion	Marion	do	12,364	168.2	2.69	.03	5.51	1.24	91.50	1.62	.....	98.87
Do	do	do	do	13,711	170.7	2.73	.04	6.75	1.59	91.65	43.51	.....	99.90
Do	do	do	do	8,136	167.6	2.68	.05	13.51	1.65	61.64	22.72	.....	99.92
Ulrich Bros....	Monterey...	Riley	do	3,272	159.1	2.55	.07	.....	.....	.....	.....	.....	.....
Rittiger Bros..	Cottonwood Falls.	Chase	do	6,800	161.6	2.59	.04	8.87	3.62	84.72	1.75	0.90	99.56
Frey Bros	Horton	Brown	do	4,721	164.5	2.63	.06	11.83	5.53	81.91	1.56	.05	100.88
A. Zechner	Alma	Wabaunsee	do	7,646	161.3	2.58	.05	9.12	.70	88.55	1.25	.....	99.62
A. W. Charles .....	.....	Jackson	do	11,005	163.5	2.62	.02	10.93	2.02	83.99	2.06	.14	99.74

KENTUCKY.

Sandstone.—The following is an analysis of blue sandstone quarried by the Rockcastle Stone Company, at their quarries at Langford, Rockcastle County, by Mr. W. M. Mew:

Analysis of sandstone quarried at Langford, Rockcastle County.

	Per cent.
Silica, SiO_2	91.075
Oxide of iron and alumina, Fe_2O_3 and Al_2O_3	4.920
Lime, CaO	1.187
Water.....	2.361
Total.....	99.543

The stone absorbs 3 per cent of water.

The same stone was tested at the Watertown Arsenal, by Capt. Ira MacNutt, with the following results:

Tests of sandstone quarried at Langford, Rockcastle County.

Test No.	Marks.	How tested.	Dimensions.			Sectional area.	Ultimate strength.	
			Height.	Compressed surface.			Total.	Per sq. in.
			<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Sq. inches.</i>	<i>Pounds.</i>	<i>Pounds.</i>
5485	Upper ledge.	On bed ..	2.01	2.00	2.02	4.04	61,250	15,160
5486	.....do	On edge .	2.03	2.00	2.02	4.04	49,320	12,208
5487	Lower ledge.	On bed ..	2.03	2.01	2.01	4.04	61,050	15,111
5488	.....do	On edge .	2.03	2.00	2.00	4.00	49,900	12,475

Crack appeared in No. 5486 at 47,500 pounds.

Crack appeared in No. 5488 at 43,600 pounds.

Fractures all pyramidal.

Limestone.—The following analysis of limestone quarried by the Caden Stone Company at their quarries in Warren County was made by Prof. W. E. Stone, of Purdue University:

Analysis of limestone quarried in Warren County.

	Per cent.
Moisture	0.38
Organic—Combustible.....	3.31
Oxide of iron, Fe_2O_3.....	.22
Silica, SiO_2 .....	.76
Lime, CaO	54.80
Oxides of potassium and sodium	6.48
Carbon dioxide, CO_2	33.00
Magnesium oxide, MgO	Trace not
Sulphuric anhydride, SO_3	deter-
Phosphoric anhydride, P_2O_5	mined.
Total.....	98.95

The following compression tests of the same stone were made February 13, 1890, at the Watertown Arsenal under the direction of Lieut. Col. D. W. Flagler:

[Compressed surfaces faced with plaster of paris to secure even bearings in the testing machine.]

Compression tests of limestone from Warren County.

Test No.	Marks.	How tested.	Dimensions.				Sectional area.	First crack.	Ultimate strength.	
			Height.	Compressed surface.					Total.	Pounds per square inch.
			<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Sq. inches.</i>	<i>Pounds.</i>	<i>Pounds.</i>		
6443	1	On bed..	4.98	5.07	4.96	25.15	170,900	170,900	6,795	
6444	1	On edge.	5.07	4.98	4.93	24.55	179,800	179,800	7,324	
6445	2	On bed..	4.94	5.05	5.05	25.30	187,850	187,850	7,425	
6446	2	On edge.	5.03	4.87	4.87	24.45	138,300	138,300	5,656	
6447	3	On bed..	5.02	5.05	5.05	25.50	172,700	172,700	6,773	
6448	3	On edge.	5.03	5.00	5.00	25.05	154,800	154,800	6,180	

Pyramidal fractures.

MAINE.

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

Analysis of granite quarried at Freeport, Cumberland County.

	Per cent.
Specific gravity	2.627
Hardness	Medium.
Iron in form of pyrite	None.
Iron in form of oxide in combination	1.872
Per cent insoluble in strong acids	95.200
Per cent soluble in dilute acids	None.
Absorption in water	None appreciable.

The following tests of granite quarried by Messrs S. L. Treat & Son at their quarries at Millbridge, Washington County, were made at the Watertown Arsenal under the direction of Maj. J. W. Reilly:

Tests of granite from Millbridge, Washington County.

COMPRESSIVE ELASTIC PROPERTIES.

[Sectional area, $4.12 \times 6.90 = 28.43$ square inches. Gaged length, 20".]

Applied loads.		In gaged length.		Remarks.
Total.	Per square inch.	Compression.	Set.	
<i>Pounds.</i>	<i>Pounds.</i>	<i>Inch.</i>	<i>Inch.</i>	
2,509	100	0	0	Initial load.
25,090	1,000	.0023	.....
50,180	2,000	.0047	.....
75,270	3,000	.0069	.....
100,360	4,000	.0089	.....
125,450	5,000	.0108	.....
100,360	4,000	.0089	.....	Modulus of elasticity E = 9,800,000.
75,270	3,000	.0069	.....
50,180	2,000	.0050	.....
25,090	1,000	.0030	.....
2,509	100	.....	.0008	
25,090	1,000	.0027	.....
50,180	2,000	.0045	.....
75,270	3,000	.0067	.....
100,360	4,000	.0088	.....
125,450	5,000	.0108	.....
100,360	4,000	.0089	.....
75,270	3,000	.0069	.....
50,180	2,000	.0049	.....
25,090	1,000	.0030	.....
2,509	100	.....	.0008	

Tests of granite from Millbridge, Washington County—Continued.

LATERAL EXPANSION.

[Gaged length, 5.5".]

Applied loads.		In gaged length.		Remarks.
Total.	Per square inch.	Compression.	Set.	
<i>Pounds.</i>	<i>Pounds.</i>	<i>Inch.</i>	<i>Inch.</i>	
2,500	100	0	0	Initial load.
125,450	5,000	.0005	-----	
2,500	100	-----	.0001	Ratio of lateral expansion to longitudinal compression, 1 to 6.8.
125,450	5,000	.0005	-----	
2,500	100	-----	.0001	

This specimen used in transverse test No. 391.

SHEARING TEST.

[Light-colored stone.]

No. of test.	Shearing dimensions.	Shearing area.	Transverse fracture developed on tension side.	Shearing strength.		Surfaces sheared.
				Total.	Per square inch.	
	<i>Inches.</i>	<i>Sq. inches.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	
309	4.02 by 5.99 by 2	48.16	43,800	135,800	2,820	One.

TRANSVERSE TESTS.

[Ends supported 20" apart; loaded over length of 1" at middle.]

No. of test.	Dimensions.		Ultimate strength.		Remarks.
	Breadth.	Depth.	Total.	Modulus of rupture R.	
	<i>Inches.</i>	<i>Inches.</i>	<i>Pounds.</i>	<i>Pounds.</i>	
391	4.12	6.09	10,540	2,069	
424	4.13	6.08	10,320	2,027	Had been previously exposed to hot and cold water baths during observations made on the coefficient of expansion by heat.

Coefficient of expansion 0.00000400 between 32° and 212° F.

The following tests of granite quarried by the Booth Bros. and Hurricane Isle Granite Company at their quarries at Hurricane Island, Jonesboro, and Waldoboro, were made by Prof. Ira H. Woolson, School of Mines, Columbia College:

Compression tests of granite quarried in Maine.

Name of quarry.	Location of quarry.	County.	No. of test.	Dimensions.		
				Height.	Breadth.	Thickness.
				<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>
Hurricane Isle.	Hurricane Island.	Knox	1709	2.017	2.018	2.022
Jonesboro Red.	Jonesboro...	Washington.	1711	2.01	2.016	2.013
Maine White	Waldoboro ..	Lincoln	1714	2.01	2.013	2.012

Name of quarry.	Location of quarry.	County.	Sectional area.	First crack.	Ultimate strength.	
					Total.	Per square inch.
			<i>Inches.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
Hurricane Isle.	Hurricane Island.	Knox	4.08	72,000	79,900	19,583
Jonesboro Red.	Jonesboro...	Washington.	4.06	84,900	100,500	24,507
Maine White	Waldoboro ..	Lincoln	4.05	.....	93,600	23,111

The following analysis of granite quarried by the Booth Bros. and Hurricane Isle Granite Company at their quarry at Waldoboro, Lincoln County, was made by Messrs. Ricketts & Banks, of New York City:

Analysis of granite quarried at Waldoboro, Lincoln County.

	Per cent.
Silica, SiO_2	73.48
Alumina, Al_2O_3	15.26
Ferrous oxide, FeO	1.42
Calcium oxide, CaO} .....	.88
Magnesia, MgO} .....	.09
Manganous oxide, MnO} .....	.10
Soda, Na_2O	3.12
Potash, K_2O	5.66
Sulphur, S (total)	Trace.
Carbonic acid, CO_2	None.
Total	100.01

The following compression tests were made at the Watertown Arsenal, under the direction of Maj. F. W. Parker, upon granite quarried by the Maine and New Hampshire Granite Company, at their quarries at North Jay, Franklin County:¹

Compression tests of granite quarried at North Jay, Franklin County.

Color of stone.	Height.	Dimensions compressed surface.			Sectional area.	First crack.	Ultimate strength.		Remarks.
							Total.	Per square inch.	
Red	<i>Inches.</i> 3.02	<i>In.</i> 3.00	<i>In.</i> 3.00	<i>Sq. in.</i> 9.00	<i>Pounds.</i> 196,800	<i>Pounds.</i> 291,300	<i>Pounds.</i> 22,567		Pyramidal fracture.
White	6.18	6.00	6.00	37.08	583,000	604,800	16,310		Do.

The following analysis of the white granite has been made by Mr. E. T. Rogers:

Analysis of granite quarried at North Jay, Franklin County.

	Per cent.
Silica, SiO ₂	71.54
Titanic oxide, TiO ₂ , and iron peroxide, Fe ₂ O ₃....	.84
Alumina, Al ₂ O ₃	14.24
Ferric oxide, Fe ₂ O ₃.....	.74
Ferrous oxide, FeO.....	1.18
Lime, CaO .....	.98
Magnesia, MgO.....	.34
Soda, Na ₂ O	3.39
Potash, K ₂ O.....	4.73
Water (at red heat) .....	.61
Sulphur, S.....	Trace.
Carbon dioxide, CO ₂	Trace.
Total	98.59

¹ For further detailed information see U. S. Geological Survey Report on Stone for 1897.

The following analysis of granite quarried by the Chase Granite Company, at their quarries at Blue Hill, Hancock County, was made by Messrs. Ricketts & Banks, of New York City:

Analysis of granite quarried at Blue Hill, Hancock County.

	Per cent.
Silica, SiO_2	73.02
Ferrous oxide, FeO	2.59
Alumina, Al_2O_3	16.22
Manganous oxide, MnO	Trace.
Lime, CaO}.....	.94
Magnesia, MgO	Trace.
Potassium oxide, K_2O	3.42
Sodium oxide, Na_2O	3.60
Sulphur, S	None.
Loss and undetermined.....	.21
Total	100.00

The following analysis of the granite, quarried by the Blue Hill Granite Company, at their quarries at Blue Hill, Hancock County, Maine, was made by Mr Henry J. Williams, chemist, of Boston, Massachusetts:

Analysis of granite from Blue Hill, Hancock County.

	Per cent.
Water, H_2O	0.27
Silica, SiO_2	74.64
Ferrie oxide, Fe_2O_3	1.56
Alumina, Al_2O_3	14.90
Lime, CaO}.....	.39
Magnesia, MgO	Trace.
Potassium oxide, K_2O	6.88
Sodium oxide, Na_2O}.....	.41
Total	99.05

Slate.—The following analysis of Monson, Piscataquis County, slate was made at the Watertown Arsenal, and published in Tests of Metals, etc., for 1892:

Analysis of slate from Monson, Piscataquis County.

	Per cent.
Silica, SiO_2	54.24
Ferric oxide, Fe_2O_3	8.39
Alumina, Al_2O_3	24.71
Calcium oxide, CaO	5.23
Magnesium oxide, MgO	2.59
Sodium oxide, Na_2O	1.43
Potassium oxide, K_2O} .....	.72
Sulphuric anhydride, SO_3	2.63
Phosphoric anhydride, P_2O_5	None.
Manganous oxide, MnO} .....	.50
Loss .....	.16
Total	100.00

The following analysis of slate, quarried by the Monson Slate Company, at their quarries at Monson, Piscataquis County, was made by Mr. L. M. Norton, of the Massachusetts Institute of Technology, at Boston, Massachusetts:

Analysis of slate quarried at Monson, Piscataquis County.

	Per cent.
Loss on ignition, including organic matter	3.88
Silica, SiO_2	56.42
Alumina, Al_2O_3	24.14
Ferrous oxide, FeO	4.46
Lime, CaO} .....	.52
Magnesia, MgO	2.28
Oxide of potassium, K_2O	5.53
Oxide of sodium, Na_2O	3.15
Total	100.38

The following tests of Monson slate were made at the Watertown Arsenal:

Transverse test of Monson slate.

Length	inches..	24
Breadth	do....	4.02
Depth	do....	6.08
Distance between supports.....	do....	19
Total ultimate strength	pounds..	40,000
Maximum fiber stress per square inch	do....	7,671

Shearing test of Monson slate.

Shearing dimensions	inches..	4.00 by 6.10
Shearing area	square inches..	48.8
First crack	pounds..	91,800
Total shearing strength	do....	107,000
Shearing strength per square inch	do....	2,192
Irregular tensile fractures	Stone did not shear	

Compression test of Monson slate.

Height	inches..	12.00
Compressed surface	do....	6.06 by 4.05
Sectional area	square inches..	24.5
First crack	pounds..	100,000
Total ultimate strength	do....	478,000
Ultimate strength per square inch	do....	19,510

Coefficient of expansion of Monson slate.

Original gaged length in air	inches..	19.9954
Temperature of bath:	F.	
Hot		194°
Cold		34°
Difference		160°
Gaged length in bath:		
Hot	inches..	20.0108
Cold	do....	19.9950
Difference	do....	.0158
Coefficient of expansion .....		.000005

The following tests of slate quarried by the East Brownville Slate Company at their quarries at Brownville, Piscataquis County, were made by Prof. W. O. Crosby, of the Massachusetts Institute of Technology, at Boston, Massachusetts:

Compression tests of slate quarried at Brownville, Piscataquis County.

Size of cube.	How applied.	Ultimate strength per square inch.
		Pounds.
1-inch cube	On bed.....	29,420
Do	do	29,120
Do	On edge.....	16,750

Transverse tests of slate quarried at Brownville, Piscataquis County.

Width.	Thickness.	Distance between supports.	Broke at—	Remarks.
<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Pounds.</i>	
6.00	1.00	11.00	2,540	Imperfect in structure.
6.00	1.00	11.00	3,550	

The following tests of slate quarried by the Monson-Burmah Slate Company, at their quarries at Monson, Piscataquis County, were made by Prof. Walter Flint, M. E., of the University of Maine:

Transverse tests of slate quarried at Monson, Piscataquis County.

[Load applied perpendicular to grain.]

No.	Size.	Span.	Load.	Modulus.
	<i>Inches.</i>	<i>Feet.</i>	<i>Pounds.</i>	<i>Pounds.</i>
1..	1 by 1 by 15	1	730	13,140
2..	1 by 1 by 15	1	800	14,400
3..	1 by 1 by 15	1	770	13,860
4..	1 by 1 by 15	1	730	13,140
5..	1 by 1 by 15	1	780	14,040
6..	1 by 1 by 15	1	760	13,680
7..	1 by 1 by 15	1	730	13,140
8..	1 by 1 by 15	1	770	13,860
9..	1 by 1 by 15	1	820	14,760
10..	1 by 1 by 15	1	780	14,040

Average per square inch, 13,778 pounds.

Transverse tests of slate quarried at Monson, Piscataquis County.

[Load applied parallel to grain.]

No.	Size.	Span.	Load.	Modulus.
	<i>Inches.</i>	<i>Feet.</i>	<i>Pounds.</i>	<i>Pounds.</i>
1...	1 by 1 by 15	1	700	12,600
2...	1 by 1 by 15	1	770	13,860
3...	1 by 1 by 15	1	740	13,320
4...	1 by 1 by 15	1	830	14,940

Average per square inch, 13,430 pounds.

Compression tests.

No.	Size.	Load.
		<i>Pounds.</i>
1..	1-inch cube	24,460
2..	.....do	24,950
3..	.....do	26,080
4..	.....do	22,700
5..	.....do	24,440
6..	.....do	25,600
7..	.....do	22,560
8..	.....do	26,770
9..	.....do	23,830
10..	.....do	24,630

Average, 24,602 pounds.

Limestone.—The following table gives the results of a number of analyses of limestone quarried in Maine:

Analyses of limestone quarried in Maine.

Name of firm quar- rying stone.	Location of quarry.		Name and address of analyst.	Substances determined.										
	Town.	County.		Cal- cium carbon- ate, CaCO ₃ .	Mag- nesium carbon- ate, MgCO ₃ .	Silica, SiO ₂ .	Fer- rous oxide, FeO.	Alumi- num oxide, Al ₂ O ₃ .	Cal- cium oxide, CaO.	Mag- nesium oxide, MgO.	Car- bon diox- ide, CO ₂ .	Mois- ture.	Organic matter.	Total.
Jas. H. McNamara.	Rockland.	Knox.	F. C. Robinson, Bowdoin College.	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
Geo. W. Bachelder.	Union	do	do	95.20	1.00	1.00	Trace.					2.70	6.28	99.77
McLeon and Stover Lime Co.	Warren	do	S. P. Sharpless, Boston, Mass.	53.52	45.13	.65						.40		100.00

MARYLAND.

Granite.—The following analysis of granite, quarried by the McClenahan & Bro. Granite Company at their quarries at Port Deposit, Cecil County, was made by Dr. H. N. Morse, professor of analytical chemistry in Johns Hopkins University:

Analysis of granite quarried at Port Deposit, Cecil County.

	Per cent.
Silica, SiO_2	73.690
Alumina, Al_2O_3	12.891
Ferric oxide, 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

Marble.—In a compression test of marble, quarried by the Beaver Dam Quarry Company at their quarries, Cockeysville, Baltimore County, Lieut. Col. Q. A. Gillmore found the crushing strength to be 22,500 pounds per square inch. The weight per cubic foot was 178 pounds.

Slate.—The following analysis of slate, quarried in the Peach Bottom slate region of York County, Pennsylvania, and Harford County, Maryland, was made by Messrs. Booth, Garrett and Blair, of Philadelphia, Pennsylvania:

Analysis of the Peach Bottom slate.

	Per cent.
Silica, SiO_2	58.370
Protoxide of iron, FeO	10.661
Alumina, Al_2O_3	21.985
Lime, CaO} .....	.300
Magnesia, MgO	1.203
Alkalies	1.933
Sulphur, S} .....	.107
Carbonic acid, CO_2 .....	.390
Carbon, C} .....	.930
Water, H_2O	4.030
Titanic acid, TiO_2	Trace.
Oxide of manganese	Trace.
Total	99.909

Sandstone.—The following analysis of sandstone, quarried by Mr. B. S. Randolph at his quarry, Frostburg, Allegany County, was made by the chemist of the Maryland Geological Survey:¹

Analysis of sandstone from Frostburg, Allegany County.

	No. 1.	No. 2.	No. 3.	No. 4.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Silica, SiO_2	99.25	99.56	99.40	97.55
Alumina, Al_2O_3.....	.61	.34	.47	2.44
Calcium oxide, CaO}.....	.11	.81	.10	.01
Manganese oxide.....	Trace.	Trace.	Trace.	Trace.
Ferric oxide, Fe_2O_3.....			.27	Trace.
Ferrous oxide, FeO}.....	.25	.20		
Total.....	100.22	100.91	100.24	100.00

¹ For further detailed information, see Vol. II, pp. 209, 210, of the Maryland Geological Survey.

Limestone.—The following table gives the results of a number of analyses of limestone quarried in Maryland:

Analyses of limestone quarried in Maryland.

Name of firm quarrying stone.	Location of quarry.		Name and address of analyst.	Substances determined.								
	Town.	County.		Calcium carbonate, CaCO_3 .	Magnesium carbonate, MgCO_3 .	Silica, SiO_2 .	Calcium oxide, CaO .	Loss on ignition.	Alumina, Al_2O_3 .	Ferric oxide, Fe_2O_3 .	Oxides of aluminum and iron.	Total.
J. W. Stimmel:				<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
No. 1.....	Walkersville.	Frederick	Prof. H. J. Patterson, College Park, Md.	93.57	0.30	4.73					1.40	100.00
No. 2.....	do	do	do	81.97	13.00	4.31					.90	100.18
M. J. Grove Lime Co.:												
Dark stone	Frederick	do	Julian O. Hargrove, 3319 N street, N.W., Washington, D.C.	97.32	2.03	.22			0.29	0.25		100.11
Light stone	do	do	do	96.79	2.86	.10			.16	Trace		99.91
P. G. Zouck & Co.	Cavetown	Washington	Lehman & Glaser, Baltimore, Md.			.47	55.51	44.02				100.00

MASSACHUSETTS.

Granite.—The following tests and analysis of granite quarried by the Rockport Granite Company at their quarries at Cape Ann, Essex County, were made at the Watertown Arsenal:¹

Analysis of granite quarried at Cape Ann, Essex County.

	Per cent.
Silica, SiO_2	81.05
Ferric oxide, Fe_2O_3	2.71
Alumina, Al_2O_3	14.70
Calcium oxide, CaO	1.10
Magnesium oxide, MgO	Trace.
Sulphuric anhydride, SO_3	None.
Phosphoric anhydride, P_2O_5	None.
Loss.....	.44
Total.....	100.00

Compression test of granite quarried at Cape Ann, Essex County.

Height.....	inches..	11.93
Compressed surface.....	do.....	6.00 by 4.00
Sectional area.....	square inches..	24.00
First crack.....	pounds..	173,000
Total ultimate strength.....	do.....	487,100
Ultimate strength per square inch.....	do.....	20,296

Shearing test.

Shearing dimensions.....	inches..	4.10 by 6.08
Shearing area.....	square inches..	49.8
First crack.....	pounds..	37,800
Total shearing strength.....	do.....	122,950
Shearing strength per square inch.....	do.....	2,469

Transverse test of granite quarried at Cape Ann, Essex County.

Length.....	inches..	24
Breadth.....	do.....	4.03
Depth.....	do.....	6.08
Distance between supports.....	do.....	19
Ultimate resistance.....	pounds..	12,500
Maximum stress.....	do.....	2,392

Coefficient of expansion of granite quarried at Cape Ann, Essex County.

Original length in air.....	inches..	19.9303
Temperature of bath:		F.
Hot.....		181°
Cold.....		33.5°
Difference.....		147.5°

¹ For further detailed information see "Tests of Metals, etc.," for 1890, 1891, and 1892.

Gaged length in bath:

Hot	inches..	19.9401
Cold	do.....	19.9310
Difference	do.....	0.0091
Coefficient of expansion .....		.00000311

The following test of granite quarried by the Shea Pink Granite Company at their quarries at Milford, Worcester County, was made at the Watertown Arsenal under the direction of Maj. J. W. Reilly:

Compression test of granite quarried at Milford, Worcester County.

Number of test	10,892
Height	inches.. 4.06
Compressed surface	inches.. 4.00 by 4.08
Sectional area	square inches.. 16.32
First crack	pounds.. 258,000
Total ultimate strength	do..... 504,100
Ultimate strength per square inch	do..... 30,888
Pyramidal fracture.	

An analysis of the same stone by Prof. H. P. Talbott, of the Massachusetts Institute of Technology, Boston, Massachusetts, is as follows:

Analysis of granite quarried at Milford, Worcester County.

	Per cent.
Silica, SiO_2	76.95
Alumina, Al_2O_3	11.15
Ferric oxide, Fe_2O_3 .....	.25
Ferrous oxide, FeO} .....	.55
Sodium oxide, Na_2O	5.60
Potassium oxide, K_2O	5.03
Moisture .....	.20
Manganous oxide, MnO	Trace.
Calcium oxide, CaO	
Magnesium oxide, MgO	
Total	99.73

The following test of crushing strength was made at the Watertown Arsenal under the direction of Maj. F. H. Parker. The stone tested was Milford pink granite, quarried by Messrs. Norcross Brothers from their quarries at Milford, Worcester County:

Test by compression of one 6-inch cube of Milford granite.

[Compressed surfaces faced with plaster of paris to secure even bearings.]

Test number.	Dimensions.			Sectional area.	Ultimate strength.	
	Length.	Compressed surface.			Total.	Per square inch.
	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Sq. inches.</i>	<i>Pounds.</i>	<i>Pounds.</i>
2596	5.98	5.83	5.96	34.75	725,700	20,883

Snapping sounds and pieces flew off at 546,000 pounds. Slight explosive sound at 674,500 pounds. Burst into small fragments and sand at the maximum load, accompanied by a loud report. One principal fragment was pyramidal shaped, with sharp apex.

The following analysis of the same stone was made at the School of Mines, Columbia University, New York City, by Prof. C. F. Chandler:

Analysis of Milford pink granite.

	Per cent.
Silica, SiO_2	76.07
Alumina, Al_2O_3	12.67
Ferric oxide, Fe_2O_3	2.00
Oxide of manganese.....	.03
Lime, CaO}.....	.85
Magnesia, MgO}.....	.10
Potash, K_2O	4.71
Soda, Na_2O	3.37
Total.....	99.80

The W. N. Flint Granite Company report the following facts relative to trap rock quarried by them at their quarries at Monson, Hampden County. The highway commissioner of Massachusetts determined what is known as the "coefficient of wear" to be 22.13. The following analysis of the same stone is credited to the Watertown Arsenal:

Analysis of trap rock quarried at Monson, Hampden County.

	Per cent.
Silica, SiO_2	52.59
Ferrie oxide, Fe_2O_3	14.55
Alumina, Al_2O_3	23.42
Lime, CaO	9.05
Magnesia, MgO} .....	.28
Manganous oxide, MnO} .....	.09
Total	99.98

Marble.—The following analysis and tests of marble quarried by Mr. W. H. Gross at his quarries at Lee, Berkshire County, were made at the Watertown Arsenal:¹

Analysis of marble quarried at Lee, Berkshire County.

	Per cent.
Silica, SiO_2	1.00
Ferrie oxide, Fe_2O_3	0.20
Alumina, Al_2O_3	
Calcium oxide, CaO	23.00
Magnesium oxide, MgO	27.98
Sulphuric anhydride, SO_3 .....	.64
Phosphoric anhydride, P_2O_5	None.
Carbon dioxide, CO_2	46.64
Loss .....	.54
Total	100.00

Compression test of marble quarried at Lee, Berkshire County.

Height	inches..	11.99
Compressed surface	inches..	5.88 by 3.98
Sectional area	square inches..	23.4
First crack	pounds..	422,300
Total ultimate strength	do....	422,300
Ultimate strength per square inch	do....	18,047

¹ For further detailed information see Tests of Metals, etc., for 1890, 1891, and 1892.

Transverse tests of marble quarried at Lee, Berkshire County.

Length.	Breadth.	Depth.	Distance between supports.	Ultimate strength.	
				Total.	Maximum fiber stress per square inch.
<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Pounds.</i>	<i>Pounds.</i>
24.0	4.01	5.98	19	7,980	1,586
23.97	3.97	6.00	19	7,940	1,584

Shearing test of marble quarried at Lee, Berkshire County.

Shearing dimensions	<i>inches.</i>	4.00 by 6.01
Shearing area	<i>square inches.</i>	48.1
First crack	<i>pounds.</i>	83,200
Total shearing strength	<i>do.</i>	98,700
Shearing strength per square inch	<i>do.</i>	2,052
Cracked at middle of length. Sheared ends.		

Coefficient of expansion of marble quarried at Lee, Berkshire County.

Original length in air	<i>inches.</i>	20.0061
Temperature of bath:		F.
Hot		189.5°
Cold		33.5°
Difference		156°
Gauged length in bath:		
Hot	<i>inches.</i>	20.0236
Cold	<i>do.</i>	20.0061
Difference	<i>do.</i>	0.0175
Coefficient of expansion .....		.00000562

The following analysis of marble quarried by the North Adams Marble and Milling Company at their quarries at North Adams, Berkshire County, was made by Prof. Wm. P. Mason of the Rensselaer Polytechnic Institute:

Analysis of marble quarried at North Adams, Berkshire County.

	Per cent.
Silica, SiO_2	0.688
Phosphoric anhydride, P_2O_5 .....	.053
Oxides of iron and aluminium .....	.061
Magnesium carbonate, MgCO_3	5.338
Calcium carbonate, CaCO_3	93.860
Total	100.000

The following is an analysis made by Prof. Arthur A. Noyes, of the Massachusetts Institute of Technology, of a serpentine marble from Westfield, Hampden County, and owned by the Westfield Marble and Sandstone Company:

Analysis of serpentine marble quarried at Westfield, Hampden County.

	Per cent.
Water, H ₂ O	0.00
Silica and silicate .....	.20
Ferrous oxide, FeO .....	.41
Calcium oxide, CaO	32.77
Magnesium oxide, MgO	19.68
Carbon dioxide, CO ₂	46.91
Total	99.97

Maj. J. W. Reilly, Watertown Arsenal, made the following compression tests of the same stone:

Compressive strength tests of Westfield serpentine marble.

No. of test.	Dimensions.			Sectional area.	First crack.	Ultimate strength.	
	Height.	Compressed surface.				Total.	Per square inch.
	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Sq. in.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
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

Sandstone.—The following table gives the results of a number of analyses of sandstone quarried in Massachusetts:

Analyses of sandstone quarried in Massachusetts.

Name of firm quarrying stone.	Location of quarry.		Name and address of analyst.	Substances found.									
	Town.	County.		Silica, SiO ₂ .	Ferric oxide, Fe ₂ O ₃ .	Alumina, Al ₂ O ₃ .	Calcium oxide, CaO.	Magnesium oxide, MgO.	Oxides of potassium and sodium.	Water, carbon dioxide, and loss.	Manganese oxide.	Total.	
Norcross Bros. (Worcester quarry).	East Long Meadow.	Hampden.	Dr. L. P. Kinnicutt, Worcester Polytechnic Institute.	Per ct. 88.89	Per ct. 1.79	Per ct. 5.95	Per ct. 0.27	Per ct.	Per ct. 0.86	Per ct. 1.83	Per ct. 0.41	Per ct. 100.00	
Norcross Bros. (Maynard quarry).	do	do	do	79.38	2.43	8.75	2.57	.....	4.68	2.79	.....	100.00
Norcross Bros. (Kibbe quarry).	do	do	Prof. C. F. Chandler, School of Mines, Columbia University, New York City.	81.38	3.54	9.44	.76	0.28	.....	4.49	.11	100.00

The following table gives the results of a number of physical tests of sandstone quarried in Massachusetts:

Physical tests of sandstone quarried in Massachusetts.

Name of firm quarrying stone.	Location of quarry.		Name and address of expert.	No. of specimens.	Compression tests.						Remarks.
	Town.	County.			Dimensions.			Sectional area.	Ultimate strength.		
					Height.	Compressed surface.			Total.	Per square inch.	
					Inches.	Inches.	Inches.	Sq. in.	Pounds.	Pounds.	
Norcross Bros. (Worcester quarry)	East Long Meadow.	Hampden	Lieut. Col. F. H. Parker, Watertown Arsenal.	4086	6.16	6.03	6.02	36.30	420,900	11,565	The specimens were tested between flat steel platforms. Their bed surfaces were faced with a thin (0.02 inch) coating of plaster of paris to secure even bearings in the testing machine. Single pyramidal fracture.
Do.	do	do	do	4087	6.13	6.02	6.01	36.18	371,800	10,276	
Norcross Bros. (Kilbo quarry).	do	do	do	3337	6.00	5.97	6.00	35.82	452,000	12,619	Tested in same way as stone from Worcester quarry. No. 3337 cracked under 451,000 pounds pressure. Single pyramid. No. 3338 cracked under 435,000 pounds pressure. Double pyramid.
Do.	do	do	do	3338	6.02	5.97	5.98	35.70	459,000	12,874	
Norcross Bros. (Maynard quarry).	do	do	do		6.16	6.03	6.02	36.30	371,100	10,223	Tested same as above. Single pyramid.
James & Marra (Kilbo red stone).	do	do	Maj. J. W. Reilly, Watertown Arsenal.		4.97	4.95	4.98	24.65	301,100	12,210	Weight per cubic foot, 154.5 pounds; first crack at 229,000 pounds; specific gravity, 2.49; ratio of absorption, 1-23.
James & Marra (Kilbo brownstone).	do	do	do		4.89	5.03	4.92	24.75	305,150	12,330	Weight per cubic foot, 154.5 pounds; first crack at 304,800 pounds; specific gravity, 2.48.

Limestone.—The following analysis of limestone quarried by the Adams Marble Company, at their quarries at Renfrew, Berkshire County, was made by Prof. E. E. Olcott:

Analysis of limestone quarried at Renfrew, Berkshire County.

	Per cent.
Calcium carbonate, CaCO_3	99.60
Magnesium carbonate, MgCO_3 .....	.49
Oxide of iron and alumina, Fe_2O_3 and Al_2O_3 .....	.55
Silica, SiO_2 .....	.63
Total	101.27

The following analysis of limestone quarried by the Cheshire Manufacturing Company, at their quarries at Cheshire, Berkshire County, was made by Messrs. Davenport and Williams:

Analysis of limestone quarried at Cheshire, Berkshire County.

	Per cent.
Silica, SiO_2	0.31
Oxide of iron and alumina, Fe_2O_3 and Al_2O_3 .....	.23
Calcium carbonate, CaCO_3	98.80
Magnesium carbonate, MgCO_3 .....	.37
Organic matter .....	.35
Total	100.06

The following are two analyses, No. 1 by Mr. P. S. Burns, No. 2 by Mr. H. P. Eddy, of lime made from limestone quarried by Messrs. J. Follet & Son, at their quarries at Renfrew, Berkshire County:

Analyses of lime from Renfrew, Berkshire County.

	No. 1.	No. 2.
	<i>Per cent.</i>	<i>Per cent.</i>
Lime, CaO	98.13	96.63
Magnesia, MgO} .....	.42	.88
Silica, SiO_2 .....	.36	.81
Alumina, Al_2O_3 .....	.15	.47
Ferrie oxide, Fe_2O_3		
Carbon dioxide, CO_2 .....	.60	.12
Water, H_2O} .....	.20	
Total	99.86	98.91

The following analysis of lime made from limestone quarried by Messrs. Hutchinson Brothers, at their quarry at New Lenox, Berkshire County, was made by Mr. W. M. Habirshaw, chemist, New York State Agricultural Society:

Analysis of lime from New Lenox, Berkshire County.

	Per cent.
Lime, CaO.....	95.66
Magnesia, MgO.....	.76
Oxides of iron and aluminum.....	.17
Silica, SiO ₂	1.14
Loss on ignition.....	3.00
Total.....	100.73

The following analysis of limestone quarried by Mr. C. H. Hastings, at his quarry at West Stockbridge, Berkshire County, was made by Mr. J. Blodget Britton, of Warrenton, Virginia:

Analysis of limestone quarried at West Stockbridge, Berkshire County

	Per cent.
Calcium carbonate, CaCO ₃	99.029
Magnesium carbonate, MgCO ₃.....	.266
Total.....	99.295

MICHIGAN.

Sandstone.—The following compression tests of sandstone quarried by the Kerber-Jacobs Redstone Company, at their quarries at Red Rock, Houghton County, were made under the direction of Maj. J. W. Reilly at the Watertown Arsenal:

Compression tests of sandstone from Red Rock, Houghton County.

Test No.	Dimensions.			Sectional area.	First crack.	Ultimate strength.	
	Height.	Compressed surface.				Total.	Per square inch.
		Inches.	Inches.				
7823	2.00	2.03	2.03	4.12	24,800	24,800	6,019
7824	2.00	2.04	2.02	4.12	21,700	21,820	5,296
7825	2.00	2.01	2.02	4.06	27,510	27,510	6,776
7826	2.00	2.01	2.00	4.02	27,440	27,440	6,826
7827	1.99	2.03	2.02	4.10	24,550	24,550	5,988
7828	2.00	2.02	2.02	4.08	24,980	24,980	6,123

Pyramidal fractures.

Limestone.—The following analyses of limestone quarried by the Sibley Quarry Company at their quarry at Trenton, Wayne County, were made by Mr. H. Harrison:

Analyses of limestone from Trenton, Wayne County.

	No. 1.	No. 2.
	<i>Per cent.</i>	<i>Per cent.</i>
Calcium carbonate, CaCO_3	98.53	97.50
Magnesium carbonate, MgCO_3 .....	.53	1.26
Oxides of iron and aluminum, Fe_2O_3 and Al_2O_3 .....	.06	.08
Silica, SiO_2 .....	.60	.40
Total	99.72	99.24

The following is a partial analysis of limestone quarried by Mr. H. O. Rose, at his quarry at Petoskey, Emmet County, made by Messrs. Strong and Dunham, of Marquette:

Partial analysis of limestone from Petoskey, Emmet County.

	<i>Per cent.</i>
Calcium carbonate, CaCO_3	87.65
Magnesium carbonate, MgCO_3	11.22*

The following analysis of limestone quarried by Mr. R. Collins at his quarry at Alpena, Alpena County, was made by the chemist of the Lake Superior Carbide Works, of Sault Ste. Marie, Michigan:

Analysis of limestone from Alpena, Alpena County.

	<i>Per cent.</i>
Calcium carbonate, CaCO_3	98.54
Magnesium carbonate, MgCO_3	1.24
Oxides of iron and aluminum, Fe_2O_3 and Al_2O_3	Trace.
Total	99.78

The following are two analyses of lime made from the same stone and analyzed by the same chemist:

Analyses of lime made from limestone quarried in Alpena, Alpena County.

	No. 3.	No. 5.
	<i>Per cent.</i>	<i>Per cent.</i>
Silica, SiO_2	1.96	3.42
Oxides of iron and aluminum, Fe_2O_3 and Al_2O_3 .....	.94	1.21
Calcium oxide, CaO	95.60	94.26
Magnesium oxide, MgO} .....	.14	.32
Carbon dioxide and water	1.36	.79
Total	100.00	100.00

The following analyses by Mr. E. J. Schneider are of lime made from limestone quarried by the Petoskey Lime Company at their quarry at Bay Shore, Charlevoix County:

Analyses of lime made from limestone quarried at Bay Shore, Charlevoix County.

	For commercial uses.	For chemical uses.
	<i>Per cent.</i>	<i>Per cent.</i>
Silica, SiO_2	1.09	0.70
Oxides of iron and aluminum, Fe_2O_3 and Al_2O_3	1.74	.66
Calcium oxide, CaO	81.83	96.80
Magnesium oxide, MgO	13.42	.67
Carbon dioxide and water	1.92	1.17
Total	100.00	100.00

MINNESOTA.

Sandstone.—The following is an analysis of the sandstone known as Kettle River sandstone, quarried by the Minnesota Sandstone Company at their quarries at Sandstone, Pine County, by Prof. N. H. Winchell:

Analysis of sandstone from Sandstone, Pine County.

	Per cent.
Water.....	0.00
Silica, SiO_2	98.69
Alumina, Al_2O_3	1.06
Iron oxide.....	Slight trace.
Calcium oxide, CaO}.....	.42
Magnesium oxide, MgO}.....	.01
Sodium oxide, Na_2O}.....	.17
Total.....	100.35

Limestone.—The following facts were obtained by Prof. N. H. Winchell, of Minnesota State University, relative to the limestone quarried by Mr. Philip Biesanz at his quarry at Winona, Winona County:

Weight per cubic foot.....	pounds..	160
Total crushing strength of 1-inch cube on bed or edge.....	do.....	65,000
Crushing strength per square inch.....	do.....	16,250

MISSOURI.

Granite.—The following compression tests of granite quarried by the Syenite Granite Company at their quarries at Graniteville, Iron County, were made by Prof. J. B. Johnson, professor of civil engineering, Washington University, St. Louis, Missouri:

Tests of granite quarried at Graniteville, Iron County.

No. of test.	Size of specimens.	Crushed at—	Crushing strength per square inch.
	<i>Sq. inches.</i>	<i>Pounds.</i>	<i>Pounds.</i>
1	3.85	93,100	24,181
2	3.78	95,700	25,317

Limestone.—The following is a table of analyses of various Missouri limestones:

Analyses of limestone quarried in Missouri.

Name of firm quarrying stone.	Location of quarry.		Name and address of analyst.	Substances determined.							
	Town.	County.		Calcium carbonate, CaCO ₃ .	Magnesium carbonate, MgCO ₃ .	Oxides of iron and aluminum.	Iron oxide.	Aluminum oxide, Al ₂ O ₃ .	Silica, SiO ₂ .	Magnesium oxide, MgO.	Total.
Marble Head Lime Co.	Springfield	Greene	R. Chauvenet & Bro., St. Louis, Mo.	P. et. 99.46	P. et.	P. et.	P. et. 0.21	P. et. 0.33	P. et.	P. et. 100.00	
Do.	Sarcoie	Jasper	Chemist of St. Louis Sampling and Testing Works, St. Louis, Mo.	98.34	Trace.	.....	.65	0.88	a .42	.....	99.69
Hannibal Lime Co.	Hannibal	Marion	do	98.80	.....	0.40	.....	.....	.08	0.02	99.30
Star Lime Co.	do	Ralls	do	99.64	0.21	.....	.....	.....	a .15	.....	100.00
Glencoe Lime and Cement Co.	Glencoe	St. Louis	do	98.36	.....	.68	.....	.....	a .70	.26	100.00
Ashgrove White Lime Association.	Ashgrove	Greene	Chas. W. Eoff	99.82	.....	.....	.01	.05	.12	Trace.	b 100.00

a Insoluble in acids.

b Contains traces of manganese and sulphur, but no phosphorus.

STONE.

The following facts relative to the limestone quarried by the Thompson & Gray Quarry Company, at their quarry at Jungs, St. Charles County, were obtained by Mr. A. S. Ferguson under the direction of Hon. M. L. Holman, water commissioner, city of St. Louis:

	Per cent.
Absorption (48 hours).....	0.40
Specific gravity.....	2.68

MONTANA.

Limestone.—The following analysis of limestone quarried by the Persell Limestone Company at their quarry at Helena, Lewis and Clarke County, was made by Mr. E. Starz:

Analysis of limestone quarried at Helena, Lewis and Clarke County.

	Per cent.
Calcium carbonate, CaCO_3	88.25
Magnesium carbonate, MgCO_3	5.70
Ferric oxide, Fe_2O_3.....	.76
Alumina, Al_2O_3.....	.18
Silica, SiO_2	1.45
Gold, silver, and zinc.....	Trace.
Total.....	96.32

NEVADA.

Granite.—The following analysis of granite quarried by Mr. John Barrett at his quarry at Reno, Washoe County, was made by Prof. J. W. Phillips:

Analysis of granite quarried at Reno, Washoe County.

	Per cent.
Silica, SiO_2	58.67
Alumina, Al_2O_3	14.89
Manganese dioxide, 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.

Granite.—Mr. Franklin C. Robinson, Maine State assayer, Brunswick, Maine, reports the following facts relative to the red and green granites quarried by the Maine and New Hampshire Granite Company at their quarries at Redstone, Carroll County:

Analyses and specific gravities of red and green granites quarried at Redstone, Carroll County.

	Red.	Green.
	<i>Per cent.</i>	<i>Per cent.</i>
Silica, SiO_2	71.44	70.42
Alumina, Al_2O_3	14.72	14.64
Ferrous oxide, FeO}.....	.46	2.34
Ferric oxide, Fe_2O_3	2.39	1.54
Sodium oxide, Na_2O	7.66	7.80
Potassium oxide, K_2O}.....	.89	.71
Magnesia, MgO}.....	.96	1.20
Rare elements (mostly oxides of titanium and thorium, TiO_2 and ThO_2)..	.78	.48
Loss at red heat (mostly water).....	.61	.61
Manganese, sulphur, calcium, phosphates	Traces.	Traces.
Total	99.91	99.74
Specific gravity	2.635	2.634

The following compression test of granite quarried by the Troy Granite Company at their quarries at Troy, Cheshire County, was made at the Watertown Arsenal, under the direction of Lieut. Col. D. W. Flagler:

Compression test of granite quarried at Troy, Cheshire County.

Test number	No..	7419
Length	inches..	5.96
Compressed surface	do....	5.84 by 5.90
Sectional area	square inches..	35.01
First crack	pounds..	525,000
Total ultimate strength.....	do....	630,100
Ultimate strength per square inch	do....	17,950
Pyramidal fracture.		

The following analysis of the same stone was made by Dr. Leonard P. Kinnicutt, of the Worcester Polytechnic Institute:

Analysis of granite quarried at Troy, Cheshire County.

	Per cent.
Silica, SiO_2	73.15
Oxides of iron and aluminum.....	17.04
Calcium oxide, CaO}.....	.81
Magnesium oxide, MgO}.....	.30
Potassium oxide, K_2O	5.74
Sodium oxide, Na_2O	2.05
Loss and undetermined.....	.91
Total.....	100.00

Professor Ricketts, of Rensselaer Polytechnic Institute, reports that the granite quarried by Messrs. Young & Sons at their quarry at Milford, Hillsboro County, has a crushing strength of 24,950 pounds to the square inch.

The following analysis of granite quarried by the Mason-New Hampshire Granite Company, at their quarry at Mason, Hillsboro County, was made by Messrs. Ricketts & Banks, 1045 John street, New York City:

Analysis of granite quarried at Mason, Hillsboro County.

	Per cent.
Silica, SiO_2	72.47
Ferrous oxide, FeO}.....	.41
Alumina, Al_2O_3	16.17
Calcium oxide, CaO	1.65
Magnesium oxide, MgO}.....	.14
Manganous oxide, MnO}.....	.39
Potassium oxide, K_2O	4.83
Sodium oxide, Na_2O	3.43
Sulphur, S.....	.02
Loss and undetermined.....	.49
Total.....	100.00

NEW JERSEY.

Granite.—The following table gives a number of analyses of trap rock quarried in New Jersey.

Dr. William C. Day, Swarthmore College, Pennsylvania, recently tested the trap rock quarried by Messrs. Hatfield & Chamberlain at their quarries at Scotch Plains, Union County, and found its crushing strength to be 35,000 pounds to the square inch.

Analyses of trap rock quarried in New Jersey.

Name of firm quarrying stone.	Location of quarry.		Name and address of analyst.	Substances determined.									
	Town.	County.		Silica, SiO ₂ .	Ferrous oxide, FeO.	Ferric oxide, Fe ₂ O ₃ .	Alum- ina, Al ₂ O ₃ .	Cal- cium oxide, CaO.	Magne- sium oxide, MgO.	Sodi- um oxide, Na ₂ O.	Potas- sium oxide, K ₂ O.	Water.	Total.
Francisco Bros.	Little Falls...	Passaic...	Dr. William C. Day, Swarthmore Col- lege, Pa.	<i>Per ct.</i> 50.81	<i>Per ct.</i>	<i>Per ct.</i> 14.66	<i>Per ct.</i> 13.25	<i>Per ct.</i> 10.96	<i>Per ct.</i> 6.97	<i>Per ct.</i> 0.76	<i>Per ct.</i> 1.71	<i>Per ct.</i> 0.88	<i>Per ct.</i> 100.00
Morris County Crushed Stone Co. ^a													
No. 1.....	Millington....	Morris....	Prof. T. B. Stillman, Stevens Insti- tute Hoboken, N.J.	49.20	.....	17.01	14.50	7.50	6.30	1.60		3.80	100.00
No. 2.....	do.....	do.....	do.....	50.03	.....	16.81	18.20	11.10	1.02	1.03		1.81	100.00
No. 3.....	do.....	do.....	do.....	51.20	.....	11.12	20.88	12.50	2.17	1.03		1.10	100.00
Freeman & Mc- Collum.	Mine Brook...	Somerset	do.....	50.61	13.91	.....	18.34	7.01	6.73	1.60	1.08	1.72	100.00

^a Samples taken from different veins. The Massachusetts Highway Commission made the coefficient of wear to be 19.64.

STONE.

Sandstone.—The following analysis of sandstone quarried by the Passaic Quarry Company, at their quarry at Avondale, Essex County, was made by Prof. T. B. Stillman, Stevens Institute of Technology:

Analysis of sandstone quarried at Avondale, Essex County.

	Per cent.
Silica, SiO_2	82.05
Alumina, Al_2O_3	5.27
Ferrie oxide, Fe_2O_3	2.71
Calcium oxide, CaO	3.35
Magnesium oxide, MgO}.....	.76
Sodium oxide, Na_2O}.....	.20
Potassium oxide, K_2O}.....	.60
Sulphuric anhydride, SO_3	Trace.
Carbon dioxide, CO_2	4.40
Water, H_2O}.....	.71
Manganous oxide, MnO	None.
Total	100.05

Limestone.—The following analysis of limestone quarried at Vernoy, Hunterdon County, by the estate of E. Weise, was made by Mr. H. B. Weaver:

Analysis of limestone quarried at Vernoy, Hunterdon County.

	Per cent.
Calcium carbonate, CaCO_3	52.450
Magnesium carbonate, MgCO_3	43.250
Iron oxide.....	1.340
Alumina, Al_2O_3.....	.545
Phosphorus, P.....	.035
Silica, SiO_2	2.280
Total	99.900

NEW YORK.

Granite.—The following analysis of granite quarried by Mr. Daniel E. Donovan at his quarry at Stony Point, in Rockland County, was made by Mr. Jos. F. Geiste, Harrison and Hudson streets, New York City.

Analysis of granite quarried at Stony Point, Rockland County.

	Per cent.
Silica, SiO_2	63.190
Ferric oxide, Fe_2O_3	10.967
Alumina, Al_2O_3	10.504
Ferrous oxide, FeO	1.508
Calcium oxide, CaO	6.120
Magnesium oxide, MgO	1.437
Potassium oxide, K_2O	4.016
Sodium oxide, Na_2O	1.916
Loss on ignition .....	.185
Undetermined .....	.157
Total	100.000

The following compression tests of granite quarried by the Pochuck Quarry Company at their quarries near Goshen, Orange County, were made by Prof. J. P. Carlin, of Cornell University:

Compression tests of granite quarried near Goshen, Orange County.

No.	Size.	Sectional area.	First crack.	Ultimate strength.	
				Total.	Per square inch.
	<i>Inches.</i>	<i>Sq. inches.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
1	2.02 by 1.98 by 2.0.	4	66,500	94,000	23,500
2	2 by 2.1 by 2	4.2	74,000	96,000	22,900

Marble.—The following analysis and tests of marble quarried by the South Dover Marble Company at their quarries at South Dover, Dutchess County, were made by Messrs. Ricketts and Banks, of New York City:

Analysis of marble quarried at South Dover, Dutchess County.

	Per cent.
Silica, SiO_2	0.70
Ferric oxide, Fe_2O_3 .....	.25
Alumina, Al_2O_3 .....	.37
Calcium oxide, CaO	30.63
Magnesium oxide, MgO	20.25
Sodium oxide, Na_2O} .....	.12
Potassium oxide, K_2O} .....	.46
Undetermined and loss .....	.56
Carbon dioxide, CO_2	46.66
Total	100.00

Tests of marble quarried at South Dover, Dutchess County.

Specific gravity	2.86
Porosity:	
Weight of sample	grams.. 143.173
Volume of sample	cubic centimeters.. 50.05
Absorption of water after soaking 24 hours	grams.. .267

The following tests of the same marble were made by Prof. Ira H. Woolson, engineering department of the school of mines, Columbia University, New York City:

Tests of marble quarried at South Dover, Dutchess County.

Test No.	How tested.	Shape of test piece.	Dimensions.		Original.		Elastic limit.	First crack.	Stress, maximum.	Compression, maximum per square inch.
			Length or height.	Diameter or breadth.	Thickness.	Area.				
			<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Sq. in.</i>		<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
1355	Bed...	Cube	1.995	2.01	2.01	4.04	Slightly.	67,800	76,100	18,836
1356	Bed...	Cube	1.985	2.02	2.00	4.04	.....	48,800	70,300	17,401
1357	Bed...	Cube	1.966	2.04	2.00	4.08	.....	77,400	85,200	20,882

Average, 10,000 pounds to the square inch.

The following analysis of marble quarried by the Snowflake Marble Company at their quarries at Pleasantville, Westchester County, New York, was made by Prof. C. F. Chandler, of Columbia University, New York:

Analysis of marble quarried at Pleasantville, Westchester County.

	Per cent.
Calcium carbonate, CaCO_3	54.12
Magnesium carbonate, MgCO_3	45.04
Ferric oxide, Fe_2O_3.....	.11
Alumina, Al_2O_3.....	.07
Silica, SiO_2.....	.10
Total	99.44

The following compression test of marble quarried by the St. Lawrence Marble Company at their quarry at Gouverneur, St. Lawrence County, was made at the Watertown Arsenal under the direction of Maj. F. H. Parker:

Compression test of marble quarried at Gouverneur, St. Lawrence County.

Compressed surface	inches..	6.11 by 6.28
Sectional area	square inches..	38.37
Total ultimate strength	pounds..	487,000
Ultimate strength per square inch	do..	12,692

The compressed surfaces were faced with a thin coating of plaster of paris to secure even bearings. Double pyramidal fracture, the bases of the pyramids forming the compressed surfaces of the stone, their apexes overlapping. Snapping sounds were heard immediately preceding the fracture.

Slate.—The following analysis and tests of slate quarried by the Hamburg Slate and Mining Company at their quarry at Hamburg, Erie County, were made by Dr. John A. Miller, chemist, 203 Ellicott street, Buffalo, New York:

Analysis of slate quarried at Hamburg, Erie County.

	Per cent.
Silica, SiO_2	67.70
Iron oxide.....	2.75
Alumina, Al_2O_3	13.49
Calcium oxide, CaO}.....	.81
Magnesia, MgO	1.29
Alkalies by difference, K_2O and Na_2O	4.91
Moisture .....	.71
Loss on ignition.....	8.34
Total.....	100.00

A sample placed in water for twenty-four hours shows an absorption of water equal to 0.27 per cent.

Upon heating a small slab to red heat for one hour and allowing it to cool, the edges showed slight flaking.

Bluestone.—The following analysis of bluestone quarried by the F. G. Clarke Bluestone Company at their quarry at Oxford, Chenango County, was made by Mr. W. E. Gifford, 54 Pine street, New York City:

Analysis of bluestone quarried at Oxford, Chenango County.

	Per cent.
Silica, SiO_2	77.56
Alumina, Al_2O_3	10.65
Oxide of iron, Fe_2O_3	4.59
Oxide of manganese .....	.09
Lime, CaO} .....	.34
Magnesia, MgO	1.22
Potassa, K_2O	2.15
Soda, Na_2O} .....	.90
Water, H_2O	1.93
Undetermined matter and loss .....	.67
Total	100.00

The following tests of the same stone were made by the assistant engineer employed in testing material for the pedestal of the statue of "Liberty Enlightening the World" in New York Harbor:

Compression tests of bluestone quarried at Oxford, Chenango County.

No.	Dimensions.	Sectional area.	Ultimate strength.	
			Total.	Per sq. inch.
	<i>Inches.</i>	<i>Sq. inches.</i>	<i>Pounds.</i>	<i>Pounds.</i>
1	3.0 by 2.936 by 2.786 ...	8.180	103,700	12,677
2	3.0 by 2.770 by 2.776 ...	7.699	103,600	13,472
3	3.0 by 2.888 by 2.802 ...	8.092	98,340	12,152

The following analysis of bluestone quarried by the Warsaw Bluestone Company at their quarries at Rock Glen, Wyoming County, was made by Dr. E. P. Harris, of Amherst College, Massachusetts:

Analysis of bluestone quarried at Rock Glen, Wyoming County.

	Per cent.
Silica, SiO_2	76.50
Alumina, Al_2O_3	14.75
Oxide of iron.....	6.35
Water.....	2.00
Total	99.60

The following tests of bluestone quarried by the Warsaw Bluestone Company at their quarries at Warsaw, Wyoming County, were made by Lieut. Col. D. W. Flagler at the Watertown Arsenal:

Tests of bluestone from Warsaw, Wyoming County.

[Stones tested on bed.]

Test No.	Weight.		Dimensions.			Sectional area.	First crack.	Ultimate strength.	
	Total.	Per cubic foot.	Height.	Compressed surface.				Total.	Per square inch.
	Lbs. oz.	Pounds.	Inches.	Inches.	Inches.	Sq. in.	Pounds.	Pounds.	Pounds.
6648	11 7½	158.2	5.01	5.00	5.00	25.00	499,200	499,200	19,968
6649	11 6	157.3	5.00	5.00	5.00	25.00	476,900	476,900	19,076
6650	11 7½	157.3	5.01	5.02	5.01	25.15	478,400	478,400	19,022

Pyramidal fractures; stones burst into fragments when the maximum load was reached.

The following analysis of bluestone quarried by the Hudson River Stone and Supply Company at their quarry at Stoneco, Dutchess County, was made by Dr. Charles F. McKenna, 221 Pearl street, New York City:

Analysis of bluestone quarried at Stoneco, Dutchess County.

	Per cent.
Silica, SiO_2	63.24
Oxides of iron and aluminum, Fe_2O_3 and Al_2O_3 ..	19.52
Calcium oxide, CaO	3.80
Magnesium oxide, MgO	1.29
Carbon dioxide, CO_2	2.72
Alkalies, etc.	9.43
Total	100.00

Limestone.—The following tables give the results of a number of analyses of limestone and lime made from limestone quarried in New York:

Analyses of limestone quarried in New York.

Name of firm quarrying stone.	Location of quarry.		Name and address of analyst.	Substances determined.												Total.
	Town.	County.		Calcium carbonate, CaCO ₃ .	Magnesium carbonate, MgCO ₃ .	Oxides of iron and aluminum.	Calcium oxide, CaO.	Magnesium oxide, MgO.	Carbon dioxide, CO ₂ .	Alumina, Al ₂ O ₃ .	Ferric oxide, Fe ₂ O ₃ .	Silica, SiO ₂ .				
D. C. Hewitt:				<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>		<i>Per cent.</i>	<i>Per cent.</i>	
Upperstratum.	Amsterdam...	Montgomery..	J. M. Sherrerd, chemist of Troy Steel and Iron Co.	.....	3.00	52.78	None.	542.97	.....	.....	.....	1.25	.....	.....	.....	100.00
Intermediate stratum.	do	do	do .....	.....	1.08	52.46	None.	542.64	.....	.....	.....	3.82	.....	.....	.....	100.00
Lowerstratum.	do	do	do .....	.....	2.76	52.12	None.	539.44	.....	.....	.....	5.68	.....	.....	.....	100.00
D. R. and H. Fogelsonger.	Williamsville.	Erie	Hugo Carlson, chemist, Johnson County, Johnstown, Pa.	96.54	1.00	.64	.....	.....	.....	.....	.....	1.17	{ S 0.10 P .01 }	.....	.....	99.46
Halderman Lime and Cement Co.	Howecave	Schoharie.	Prof. Chas. A. Schaeffer, president Iowa State University.	97.24	1.39	.73	.....	.....	.....	.....	.....	1.27	{ SO ₃ Trace. Fe ₂ O ₃ None. }	.....	.....	100.63
Ossining Lime Co.	Ossining	Westchester..	Ledoux Chemical Laboratory	.....	.23	30.94	22.28	47.14	.....	.....	.....	6.29	.....	.....	.....	99.89
Cobleskill Quarry Co.	Cobleskill	Schoharie.	Dr. C. F. McKenna, 221 Pearl street, New York City.	.....	.97	51.05	1.65	41.60	.....	.....	.....	4.31	S	.29	.....	100.17
F. W. Jones.....	Hudson.....	Columbia.....	Professor Egleston .....	.....	.....	51.40	2.23	41.19	0.63	1.82	1.84	{ P .15 H ₂ O .27 }	.....	.....	.....	99.68
Do.....	do	do	Chemist of Burden Iron Works.	91.70	3.51	.....	.....	.....	.....	1.01	.55	{ P .02 SO ₃ .05 }	.....	.....	.....	98.73
Keenan Lime Co...	Smiths Basin ..	Washington ..	Chemist of Albany and Rensselaer Iron and Steel Co., Troy, N. Y.	.....	.....	54.15	.39	42.95	.08	.02	.97	{ Fe ₂ O ₃ .01 H ₂ O 1.47 }	.....	.....	.....	100.10

a Carbon dioxide, CO₂, loss and undetermined.

b Insoluble in acids.

c Includes 0.15 per cent SO₃.

d Includes 0.06 per cent organic matter.

STONE.

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Analyses of lime made from limestone quarried in New York.

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MINERAL RESOURCES.

Name of firm quarrying stone.	Location of quarry.		Name and address of analyst.	Substances determined.								Total.
	Town.	County.		Calcium oxide, CaO.	Magnesium oxide, MgO.	Oxides of iron and aluminum.	Alumina, Al ₂ O ₃ .	Ferrie oxide, Fe ₂ O ₃ .	Silica, SiO ₂ .			
Robinson & Ferris.....	Mechanicville.....	Washington..	M. L. Griffin, Mechanicville, N. Y.	<i>Per ct.</i> 97.64	<i>Per ct.</i> 0.80	<i>Per cent.</i>	<i>Per cent.</i> 1.04	<i>Per ct.</i> 0.25	<i>Per cent.</i> 0.23	<i>Per cent.</i>	<i>Per cent.</i>	99.66
E. R. Alvord & Co.....	Jamesville.....	Onondaga....	F. E. Englehardt, 1 th D., Syracuse, N. Y.	91.93	3.96	2.03	.....	.....	a 1.88	SO ₄ 0.73	.....	99.63
Chazy Marble Lime Co	Chazy.....	Clinton.....	Enrique Tenceda, Troy, N. Y.	97.08	1.40	.....	.14	.12	.79	.....	.....	99.53
Brown Cement Co.....	Manlius.....	Onondaga....	Dr. Wm. M. Smith, Syracuse, N. Y.	47.48	18.55	13.67	.....	.....	20.30	.....	.....	100.00
Keenan Lime Co.....	Smiths Basin...	Washington..	Prof. J. H. Appleton.....	93.50	Trace.	.58	.....	.....	a 1.00	{ CO ₂ H ₂ O }	2.08	99.22
Do.....	.....do.....	.....do.....	Chemist of Albany and Rensselaer Iron and Steel Co., Troy, N. Y.	94.07	.79	.....	.20	.07	1.93	{ P ₂ O ₅ CO ₂ }	.01 3.04	100.11

a Insoluble in acid.

NORTH CAROLINA.

Sandstone.—The following analysis of sandstone quarried by Mr. A. H. McNeill at his quarry at Carthage, Moore County, was made by Dr. Charles Cresson, of Philadelphia, Pennsylvania.

Analysis of sandstone quarried at Carthage, Moore County.

	Per cent.
Silica, SiO_2	79.63
Oxide of iron	4.16
Alumina, Al_2O_3	7.16
Calcium oxide, CaO} .....	.92
Manganese oxide .....	.34
Magnesium oxide, MgO	2.63
Sulphuric anhydride, SO_3 .....	.50
Oxides of potassium and sodium, water and loss.	4.66
Total	100.00

The following compression test of the same stone was made by Messrs. Tinius Olsen & Co., of Philadelphia, Pennsylvania:

Compression test of sandstone quarried at Carthage, Moore County.

Height	inches..	2.229
Compressed surface	do....	2.187 by 2.33
Sectional area	square inches..	4.883
Total ultimate strength	pounds..	62,240
Ultimate strength per square inch	do....	12,750

Weight per cubic foot, 159 pounds.

OHIO.

Sandstone.—The following analysis of sandstone quarried by the Chippewa Sand and Stone Company at their quarry at Massillon, Wayne County, was made by Mr. E. B. Baltzley:

Analysis of sandstone quarried at Massillon, Wayne County.

	Per cent.
Silica, SiO_2	97.36
Alumina, Al_2O_3	2.28
Calcium oxide, CaO} .....	.05
Magnesium oxide .....	.08
Iron	Trace.
Total	99.77

The following analyses of sandstone quarried by Mr. F. O. Neeb at his quarries at Lancaster, Fairfield County, was made by Mr. Hugo Blanck, of Pittsburg, Pennsylvania:

Analyses of sandstone quarried at Lancaster, Fairfield County.

	Yellow (No. 1).	Pale (No. 11).
	<i>Per cent.</i>	<i>Per cent.</i>
Silica, SiO_2	96.822	97.762
Alumina, Al_2O_3.....	.505	.731
Oxide of iron .....	.670	.510
Lime, CaO} .....	.040	.122
Magnesia, MgO} .....	.005	.003
Water, H_2O	1.281	.511
Total.....	99.323	99.639

The following compression tests of the same stone were made by Mr. M. J. Becker, chief engineer of the Pittsburg, Cincinnati, Chicago and St. Louis Railroad:

Compression tests of sandstone quarried at Lancaster, Fairfield County.

No. of test.	Dimensions.			Sectional area.	Ultimate strength.	
	Height.	Compressed surface.			Total.	Per square inch.
	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Sq. inches.</i>	<i>Pounds.</i>	<i>Pounds.</i>
1	5.9	6.00	5.90	35.40	210,600	5,950
2	5.8	5.85	5.85	34.22	231,400	6,762

The following is the statement of an analysis of the sandstone quarried by Messrs. Reynolds Brothers at their quarries at Freeport, Harrison County, Ohio, by Mr. Charles D. Rawling, chemist, of Wheeling, West Virginia:

Analysis of Freeport, Harrison County, sandstone.

	Per cent.
Dried at 100° C.	
Silica, SiO_2	95.17
Alumina, Al_2O_3 .....	.73
Ferrie oxide, Fe_2O_3	2.53
Lime, CaO} .....	.36
Magnesia, MgO	Trace.
Loss on ignition	1.17
Total	99.96
Water absorbed	6.08

The following facts relating to the sandstone quarried by the Rarden Stone Company at their quarries at Rarden, Scioto County, were obtained by Prof. Edward Orton, jr., Ohio State University:

Dried sample at 250° F.

Soaked sample 24 hours in water.

Percentage of absorption, 2.25.

Exposed sample 12 hours while wet to a temperature of 20° F., then thawed. Re-soaked for a short time and froze again. On thawing, practically no change in the stone was noticeable.

Limestone.—The following tables give the results of a number of analyses of limestone and lime made from limestone quarried in Ohio:

Analyses of limestone quarried in Ohio.

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MINERAL RESOURCES.

Name of firm quarrying stone.	Location of quarry.		Name and address of analyst.	Substances determined.					Totals.
	Town.	County.		Calcium carbonate, CaCO ₃	Magnesium carbonate, MgCO ₃	Oxides of iron and aluminum.	Siliceous matter insoluble in acids.		
				<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>		<i>Per cent.</i>
Snowflake Lime Co.....	Bowling Green...	Wood.....	Prof. Edward Orton, State geologist.	53.88	44.91	0.40	0.30		99.49
M. Daum & Son.....	Carey.....	Wyandot.....	do.....	56.40	41.99	.31	.48		99.18
T. J. Price & Co.....	Columbus.....	Franklin.....	do.....	94.80	1.21	.80	3.20		100.01
D. P. Lloyd & Co.....	Fostoria.....	Wood.....	do.....	52.00	45.26	2.70	Trace.		99.96
N. E. Gregg & Co.....	Genoa.....	Ottawa.....	do.....	54.30	45.14	.16	.23		99.83
Olemacher Lime Co.....	Sandusky.....	Erie.....	do.....	89.68	8.34	.35	1.51		99.28
J. Kingham.....	Rockyridge.....	Ottawa.....	do.....	54.10	44.27	.29	.87		99.53
Sugar Ridge Lime and Stone Co.	Sugarridge.....	Wood.....	do.....	55.23	43.12	.69	.84		99.88
O. D. Brown.....	Rex.....	Miami.....	do.....	95.60	3.93	.40	.07		100.00
Casparis Stone Co.....	Cold Springs.....	Clark.....	Ellis Lovejoy, Columbus, Ohio.	54.05	44.94	.23	.49		99.71
Do.....	Columbus.....	Franklin.....	Chemist of Cleveland Rolling Mills.	93.21	4.70	1.74			99.65
Norris & Christian Lime and Stone Co.	Marion.....	Marion.....	do.....	86.22	9.27	2.30	2.86	P 0.11	100.76
N. B. Eddy.....	Luckey.....	Wood.....	G. A. Kirchmaier, Toledo, Ohio...	54.10	44.90	.36	4.45		99.81
Duncan & Bussard.....	Williston.....	Ottawa.....	do.....	53.90	44.82	.21	4.21	P ₂ O ₅ .001 Al ₂ O ₃ .33	99.141
J. W. Ruhl.....	Covington.....	Miami.....	J. D. Lisle.....	53.60	37.11		4.77	Fe ₂ O ₃ .67	106.34
W. E. Marsh.....	Elfort.....	Scioto.....	Chemist of Burgess Steel and Iron Works, Portsmouth, Ohio.	97.32	.45	1.40	4.60		99.77
Doherty & Co.....	Toledo.....	Wood.....	Hugo Blanck, Pittsburg, Pa.....	57.30	36.70		4.95	H ₂ O .21 Al ₂ O ₃ .02	99.56

Analysis of lime made from limestone quarried in Ohio.

Name of firm quarrying stone.	Location of quarry.		Name and address of analyst.	Substances determined.						
	Town.	County.		Alumina, Al ₂ O ₃	Ferrie oxide, Fe ₂ O ₄	Silica, SiO ₂	Calcium oxide, CaO	Magne- sium oxide, MgO	Water.	Totals.
L. McCollum & Co.....	Tiffin	Seneca	Prof. Otto Wulfe, Pittsburg, Pa..	<i>Per cent.</i> 0.10	<i>Per cent.</i> 0.07	<i>Per cent.</i> 1.61	<i>Per cent.</i> 57.44	<i>Per cent.</i> 40.36	<i>Per cent.</i> 0.41	<i>Per cent.</i> 99.99

^a Given as silica, SiO₂.

^b Includes also organic matter, 0.73 per cent, and manganese oxide, 0.73 per cent.

^c Includes also 0.32 per cent organic matter.

OREGON.

Sandstone.—The following is a statement of the results of analysis and physical test of sandstone quarried by the Victor Sandstone Company at their quarries at Chitwood, Lincoln County, by Maj. J. W. Reilly at the Watertown Arsenal:

Analysis of sandstone quarried at Chitwood, Lincoln County.

	Per cent.
Silica, SiO_2	72.45
Oxide of iron.....	10.80
Alumina, Al_2O_3	12.60
Lime, CaO	4.10
Magnesia, MgO	Trace.
Total.....	90.95

Compression test.

Sectional area, 4.03 by 4.20 by 6.07=24.46 square inches.

First crack at 145,000 pounds.

Ultimate strength, 153,700=6,284 pounds per square inch; pyramidal fracture.

The following analysis of sandstone, quarried by the Forest Grove Stone Company at their quarries at Forestgrove, Washington County, was made by Mr. A. R. Sweetser, instructor in chemistry at T. A. & P. U., Forestgrove, Oregon:

Analysis of sandstone quarried at Forestgrove, Washington County.

	Per cent.
Silica, SiO_2	55.21
Ferric Oxide, Fe_2O_3	14.75
Alumina, Al_2O_3	17.87
Calcium oxide, CaO	2.10
Alkalies.....	4.98
Loss on ignition.....	5.09
Total.....	100.00

Specific gravity, 2.35.

PENNSYLVANIA.

Granite.—The following analysis of trap rock, quarried by the John T. Dyer Company at their quarry at Birdsboro, Berks County, was made by Dr. Hermann Fleck, of the University of Pennsylvania:¹

Analysis of trap rock quarried at Birdsboro, Berks County.

	Per cent.
Silica, SiO_2	46.87
Alumina, Al_2O_3	13.36
Ferrous oxide, FeO	2.71
Ferric oxide, Fe_2O_3	9.79
Calcium oxide, CaO	14.70
Magnesium oxide, MgO	4.35
Sodium oxide, Na_2O	4.64
Potassium oxide, K_2O	2.01
Titanium oxide, TiO_2	1.98
Total	100.41

Marble.—The following analysis of marble, quarried by Mr. J. H. Black at his quarries in Dauphin County, near Annville, was made by Prof. G. G. Pond of the chemical department at State College, Pennsylvania:

Analysis of marble quarried in Dauphin County, near Annville.

	Per cent.
Carbonate of calcium, CaCO_3	95.10
Carbonate of magnesium, MgCO_3	3.96
Silica, SiO_2	1.07
Oxide of iron .....	.23
Alumina, Al_2O_3.....	.14
Phosphorus, P.....	.00
Organic matter.....	Slight tr.
Total	100.50
Specific gravity	2.67
Crushing strength, pounds per square inch.....	12,210

¹ For further detailed information see United States Geological Survey Report on Stone for 1897.

Slate.—The following analysis of "Peach Bottom" slate quarried by Messrs. J. Humphreys & Co. at their quarry at Delta, York County, was made by Dr. A. S. McCreath:

Analysis of slate quarried at Delta, York County.

	Per cent.
Silica, SiO_2	55.880
Titanium oxide, TiO_2	1.270
Alumina, Al_2O_3	21.849
Ferrous oxide, FeO	9.033
Manganous oxide, MnO} .....	.586
Cobaltous oxide, CoO	Trace.
Calcium oxide, CaO} .....	.155
Magnesia, MgO	1.495
Potassium oxide, K_2O	3.640
Sodium oxide, Na_2O} .....	.460
Water, H_2O	3.385
Pyrite, FeS_2 .....	.051
Sulphuric anhydride, SO_3 .....	.022
Carbon, C	1.794
Total	99.620

The following analysis of slate, quarried by the East Bangor Consolidated Slate Company at their quarries at East Bangor, Northampton County, was made by Mr. Henry Leffman, of Philadelphia:

Analysis of slate quarried at East Bangor, Northampton County.

	Per cent.
Silica, SiO_2	68.620
Iron oxide	4.200
Alumina, Al_2O_3	12.680
Calcium carbonate, CaCO_3	2.337
Magnesium	3.759
Alkalies	3.730
Moisture and combustible matter	4.470
Total	99.796
Summary:	
Silicates	89.160
Carbonates	6.096
Moisture and combustible matter	4.470

Sandstone.—The following table gives the results of a number of specific-gravity determinations and analyses of sandstone quarried in Pennsylvania:

The following tables give the results of a number of physical tests and analyses of sandstone quarried in Pennsylvania:

Crushing strength, specific gravity, and ratio of absorption of sandstone quarried in Pennsylvania.

Name of firm quarrying stone.	Location of quarry.		Name and address of authority.	Crushing strength per square inch.	Number of specimens tested.	Specific gravity.	Weight per cubic foot.	Ratio of absorption.
	Town.	County.						
Hummelstown Brown Stone Co.....	Hummelstown...	Dauphin...	Richlé Brothers, Philadelphia, Pa.....	<i>Pounds.</i> 13,097	3		<i>Pounds.</i>	
Do.....	do.....	do.....	Merrill, stones for building and decorating	12,810				
Hummelstown Brown Stone Co., No. 3.....	do.....	do.....	Richlé Brothers, Philadelphia, Pa.....	14,630	4			
Hummelstown Brown Stone Co., No. 4.....	do.....	do.....	do.....	10,933	4			
Hummelstown Brown Stone Co., No. 3.....	do.....	do.....	Rose Polytechnic Institute.....	14,600	3	2.66	146.0	1-27
Do.....	do.....	do.....	Watertown Arsenal.....	14,753	3			1-37
George Brook.....	Birdsboro.....	Berks.....	do.....	11,448	3			
Lumberville Granite Co.....	Lumberville.....	Bucks.....	Fairbanks's Laboratory, New York.....	19,895	4			1-93
Do.....	do.....	do.....	Booth, Garrett & Blair, Philadelphia, Pa.....	24,625	2	2.60	162.5	1-88
Do.....	do.....	do.....	Garrison & Olsen, Philadelphia, Pa.....	22,025	8			
Paul A. Oliver.....	Laurel Run.....	Luzerne.....	School of Mines, Columbia College.....	22,250		2.66	166.1	
Do.....	do.....	do.....	Cornell University.....	17,600	12	2.66	166.1	1-900
Pennsylvania Quarry Co.....	White Haven.....	do.....	Watertown Arsenal.....	29,232	3			
Do.....	do.....	do.....	do.....	32,397	7			

STONE.

Analyses of sandstone quarried in Pennsylvania.

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MINERAL RESOURCES.

Name of firm quarrying stone.	Location of quarry.		Name and address of analyst.	Specific gravity.	Substances determined.											
	Town.	County.			Silica, SiO_2 .	Alumina, Al_2O_3 .	Ferric oxide, Fe_2O_3 .	Calcium oxide, CaO .	Magnesium oxide, MgO .	Potassium oxide, K_2O .	Sodium oxide, Na_2O .	Ferrous oxide, FeO .	Manganese dioxide, MnO_2 .	Water, H_2O .	Total.	
Hummelstown Brown Stone Co.—																
Blue	Hummelstown..	Dauphin....	From chemical laboratory of State College, Pa.	2.657	Per ct. 90.34	Per ct. 4.35	Per ct. 1.09	Per ct. 0.95	Per ct. 0.17	Per ct. 1.30	Per ct. 0.19	Per ct. 0.74	.....	Per ct. 0.61	Per ct. 99.74
Brown.....	do	do	do	2.669	88.96	4.74	2.19	.86	.44	1.31	.24	.....	.....	.87	99.61
Swatara Brown Stone Co.	Swatara	Schuylkill ..	do .....	.....	91.52	3.80	2.02	.50	.22	a 1.20	.....	.....	.....	.74	100.00
Mount Gretna	Gretna	Washington ..	do	2.695	91.07	2.68	3.29	.23	.33	1.12	.24	.....	.....	.73	99.69
John Westley	Mohrsville	Berks	do	2.73	84.96	7.78	3.71	.19	.38	1.11	.43	.....	0.18	1.40	100.05
Moody & Edwards	Grenoble	Bucks	do	2.66	79.08	12.42	2.50	.....	.....	2.02	2.01	.....	.09	.55	99.67
Henry Mitchell	Newtown	do	do	2.66	82.34	11.46	1.67	.37	.19	.17	3.76	.....	.07	.80	100.13
Yardley	Yardley	do	do	2.675	82.72	10.29	1.92	.17	.36	.10	2.92	.....	.16	1.20	99.84
Laurel Run Red Stone Co.	Laurel Run	Luzerne	A. A. Breneman, New York City.	2.666	694.00	Trace.	1.98	1.10	1.00	.....	.....	Trace.	.....	c 1.92	100.00
Pennsylvania Quarry Co.	White Haven	do	Chemist of Crane Iron Co.	.....	90.36	2.17	d 1.15	2.00	Trace.	.....	.....	.....	.....	.....	95.68
Edge Hill Mica Schist Co.	Edge Hill	Montgomery ..	Chemist of Pennsylvania Steel Co., Steelton, Pa.	.....	89.69	6.83	2.21	.07	.16	1.73	.....	.....	.....	.....	100.00
Webster Keasey	Rough Run	Butler	James O. Handy, chemist, Pittsburg, Pa.	.....	97.96	1.15	.11	.....	.....	.....	.24	.....	.....	e .54	100.00

a Includes alkalis and loss.

d Given as protoxide; evidently a mistake.

b Silica and insoluble residue.

c Volatile matter—water and carbonic acid.

e Contains water and organic matter.

Bluestone.—The following analysis of bluestone quarried by Mr. Frank Carlucci at his quarry at Lathrop, Susquehanna County, was made by Mr. D. W. Humphrey, of Scranton, Pennsylvania.

Analysis of bluestone quarried at Lathrop, Susquehanna County.

	Per cent.
Silica, SiO_2	91.40
Alumina, Al_2O_3	6.64
Ferric oxide, Fe_2O_3 .....	.16
Water, H_2O	1.28
Total	99.48

Limestone.—The following tables give the results of a number of analyses

Analyses of limestone

Name of firm quarrying stone.	Location of quarry.		Name and address of analyst.
	Town.	County.	
Carbon Limestone Co.....	Youngstown.....	Lawrence.....	S. W. McKeown
Stacey & Co.....	Wrightsville.....	York.....	A. S. McCreath, Harrisburg, Pa. .
Do.....	Hellam.....	do.....	do.....
R. McCoy Lime Co.....	Bridgeport.....	Montgomery..	Chas. F. Reader.....
Chickies Iron Co.....	Chickies.....	Lancaster.....	Chickies Iron Co. chemist.....
James Copeland.....	Downingtown.....	Chester.....	Jas. H. Eastwick, Germantown, Pa.
Abraham K. Stauffer.....	Esterly.....	Berks.....	Chas. T. Davies.....
Wm. H. Gelbach.....	Fairfield.....	Adams.....	Franklin Menger, Ph. D.....
Geo. W. Musselman.....	do.....	do.....	do.....
Geo. W. Bachman.....	Freemansburg.....	Northampton.	Irwin A. Bachman, Ph. D., Allentown, Pa.
J. King McLanahan, Jr.....	Frankstown.....	Blair.....	Chemist of Shoenberger Steel Co.
Wm. B. Rambo:			
Quarry No. 1.....	Norristown.....	Montgomery..	Booth, Garrett & Blair, Philadelphia, Pa.
Quarry No. 2.....	do.....	do.....	do.....
Jas. B. Smith:			
No. 1.....	Reedsville.....	Mifflin.....	R. Kent, Burnham, Pa.....
No. 2.....	do.....	do.....	do.....
Jno. C. Fisher.....	Richland Station..	Lebanon.....	A. S. McCreath, Harrisburg, Pa. .
S. A. Royer.....	do.....	do.....	do.....
Little Mining Co.....	Little.....	Somerset.....	Chemist of W. Dewees Wood Co., McKeesport, Pa.
Winfield Mineral Co.....	West Winfield....	Butler.....	Chemist of Pennsylvania Salt Mfg. Co., Natrona, Pa.
Jos. E. Thorpp.....	Everett.....	Bedford.....	Ry company chemist.....
Israel Stettler.....	Troxlerstown.....	Lehigh.....	H. R. Hartsell.....
W. L. Heisey & Co.....	Rheems.....	Lancaster.....	State chemist, Harrisburg, Pa. .

Analyses of lime made from lime

Jno. Yeager.....	Dalmatia.....	Northumberland.	Dr. Wm. Frazer, State chemist...
R. McCoy Lime Co.....	Bridgeport.....	Montgomery..	Chas. I. Reader.....

of limestone and lime made from limestone quarried in Pennsylvania:
quarried in Pennsylvania.

Calcium carbonate, CaCO ₃	Magnesium car- bonate, MgCO ₃	Oxides of iron and aluminum	Calcium oxide, CaO	Magnesium oxide, MgO	Ferric oxide, Fe ₂ O ₃	Aluminum oxide, Al ₂ O ₃	Siliceous matter in- soluble in acids	Silica, SiO ₂	Loss on ignition	Phosphoric anhy- dride, P ₂ O ₅	Potassium oxide, K ₂ O	Phosphorus, P	Sulphur, S	Total
P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.	P. ct.
96.43	0.40	1.60	.....	.....	.....	.....	.....	1.50	.....	.....	.....	0.02	0.08	100.00
54.20	44.51	.66	.....	.....	.....	.....	.....	.56	.....	.....	.....	.....	.....	99.90
92.14	6.50	.14	.....	.....	.....	.....	.....	.12	.....	.....	.....	.....	.....	99.90
55.70	41.97	.72	.....	.....	.....	.....	.....	1.58	.....	.....	.....	.....	.....	99.97
51.00	48.49	.....	.....	.....	.....	0.31	.....	.36	.....	.....	.....	.....	.....	100.16
54.15	45.20	.....	.....	.....	0.37	.....	.....	.....	.....	.....	.....	.....	.....	99.72
55.58	30.21	1.22	.....	.....	.....	.....	3.80	.....	.....	.....	.....	.....	.....	99.90
85.23	2.78	1.50	.....	.....	.....	.....	10.30	0.19	.....	.....	.....	.....	.....	100.00
86.91	3.11	.....	.....	.....	.60	.....	.....	8.85	.....	0.12	0.38	.....	.....	99.97
89.09	5.10	.....	.....	.....	.32	1.61	.....	2.18	.....	.....	.....	.....	.....	98.38
.....	.....	1.00	54.00	Nemo.	.....	.....	.....	1.06	43.60	.....	.....	.....	.....	100.76
53.49	45.76	.....	.....	.....	.45	.....	.20	.....	.....	.....	.....	.....	.....	99.90
54.04	45.51	.....	.....	.....	.20	.....	.25	.....	.....	.....	.....	.....	.....	100.00
95.75	2.03	1.36	.....	.....	.....	.....	.....	1.69	.....	.....	.002	.....	.....	100.832
96.24	2.86	.61	.....	.....	.....	.....	.....	.33	.....	.....	.002	.....	.....	100.042
99.02	.67	.19	.....	.....	.....	.....	.....	.07	.....	.....	.003	.....	.....	99.953
98.96	.91	.24	.....	.....	.....	.....	.....	.39	.....	.....	.002	.....	.....	99.902
92.12	2.35	2.00	.....	.....	.....	.....	3.53	.....	.....	.....	.02	.....	.....	100.02
95.10	1.12	1.00	.....	.....	.....	.....	2.78	.....	.....	.....	.....	.....	.....	100.00
.....	.....	30.18	19.48	.....	.....	.89	.....	4.48	.....	.....	.....	.....	.....	55.03
86.50	1.21	2.30	.....	.....	.....	.....	.....	7.22	.....	.....	.....	.....	.....	97.23
97.95	.98	.11	.....	.....	.....	.....	.96	.....	.....	.....	.....	.....	.....	100.00

stone quarried in Pennsylvania.

.....	6.80	81.38	1.34	.....	.....	2.43	.....	7.05	0.35	0.65	.....	.....	.....	100.00
.....	1.35	58.33	37.37	.....	.....	.....	.....	2.95	.....	.....	.....	.....	.....	100.00

RHODE ISLAND.

Limestone.—The following analysis of limestone quarried by Mr. Herbert Harris at his quarry at Lime Rock, Providence County, was made by Prof. J. H. Appleton, of Brown University:

Analysis of limestone quarried at Lime Rock, Providence County.

	Per cent.
Moisture	0.040
Oxide of iron .....	.011
Alumina, Al_2O_3 .....	.309
Siliceous matter, insoluble	2.748
Calcium carbonate, $CaCO_3$	88.233
Magnesium carbonate, $MgCO_3$	8.797
Total	100.138

SOUTH CAROLINA.

Granite.—The following compression test of granite quarried by the Georgia-Carolina Granite Company at their quarry at Carlisle, Union County, was made when the quarry was operated by A. J. Salenas & Son, at the Watertown Arsenal:

Compression test of granite quarried at Carlisle, Union County.

Dimensions.	Sectional area.	First crack.	Ultimate strength.	
			Total.	Per square inch.
<i>Inches.</i>	<i>Sq. inches.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
1.99 by 2.03 by 2.03	4.12	112,000	120,100	29,150

SOUTH DAKOTA.

Sandstone.—The following compression test of sandstone quarried by the Burke Stone Company at their quarry at Hot Springs, Fall River County, was made at the Watertown Arsenal:

Compression test of sandstone quarried at Hot Springs, Fall River County.

Test No.	Height.	Compressed surface.	Sectional area.	First crack.	Ultimate strength.	
					Total.	Per square inch.
	<i>Inches.</i>	<i>Inches.</i>	<i>Sq. inches.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
8721	1.02	2.05 by 2.04	4.18	28,900	28,900	6,914

The following tests of sandstone quarried by the Baker Quarry Company at their quarries at Rapid City, Pennington County, were made by Mr. William F. M. Goss, at Purdue University:

Tests of sandstone quarried at Rapid City, Pennington County.

Kind of stone.	Area.	Total crushing strength.	Strength per square inch.
	<i>Square inches.</i>	<i>Pounds.</i>	<i>Pounds.</i>
Gray	4.42	50,618	11,452
White	4.40	31,080	7,052
Red	4.14	25,320	6,116
Buff	4.34	39,220	9,037
Variegated	4.14	36,855	8,902
Brown	4.43	25,825	5,829

Limestone.—The following is a partial analysis of limestone quarried by the Deadwood and Delaware Smelting Company at their quarry at Deadwood, Lawrence County, made by Mr. J. V. N. Door:

Partial analysis of limestone quarried at Deadwood, Lawrence County.

	Per cent.
Siliceous matter, insoluble	1.80
Oxides of iron and aluminum	Trace.
Calcium oxide, CaO	33.80
Magnesium oxide, MgO	15.70

TENNESSEE.

Limestone.—The following analysis of lime made from limestone quarried by the Arlington Lime Company at their quarry at Erin, Houston County, was made by Prof. J. C. Wharton, Nashville, Tenn.:

Analysis of lime made from limestone quarried at Erin, Houston County.

	Per cent.
Calcium oxide, CaO	97.82
Calcium carbonate, CaCO ₃	1.27
Magnesium oxide, MgO .....	.12
Ferrie oxide, Fe ₂ O ₃ .....	.23
Aluminum oxide, Al ₂ O ₃ .....	.13
Siliceous matter, insoluble in hydrochloric acid ..	.43
Total	100.00

The following analysis of lime made from limestone quarried by the Gager Lime and Manufacturing Company at their quarry at Sherwood, Franklin County, was made by the chemist of the Proctor & Gamble Company, Cincinnati, Ohio:

Analysis of lime made from limestone quarried at Sherwood, Franklin County.

	Per cent.
Calcium oxide, CaO.....	97.89
Calcium carbonate, CaCO ₃.....	.27
Magnesium carbonate, MgCO ₃	1.05
Silica, SiO ₂.....	.56
Oxides of iron and aluminum.....	.22
Total.....	99.99

TEXAS.

Limestone.—The following analysis of limestone, quarried by Mr. D. R. Boone at his quarry at Oglesby, Coryell County, Texas, was made by Prof. H. H. Harrington, of the Agricultural and Mechanical College and Experiment Station, of Texas:

Analysis of limestone quarried at Oglesby, Coryell County.

	Per cent.
Siliceous matter.....	1.09
Organic matter.....	.52
Iron oxide.....	.35
Calcium oxide, CaO.....	54.02
Magnesium oxide, MgO.....	.12
Sulphur trioxide, SO ₃.....	.17
Carbon dioxide, CO ₂	43.96
Total.....	100.23

The following analyses of lime, made from limestone quarried by the Austin White Lime Company at their quarries at McNeil, Travis County, were made by Prof. James R. Bailey, of the chemical department, University of Texas:

Analyses of lime made from limestone quarried at McNeil, Travis County.

	No. 1.	No. 2.
	Per cent.	Per cent.
Loss of weight at white heat.....	1.41	1.02
Residue insoluble in acids.....	.25	.15
Oxides of iron and aluminum, Fe ₂ O ₃ and Al ₂ O ₃.....	.15	.16
Calcium oxide, CaO.....	97.46	97.82
Undetermined.....	.73	.85
Total.....	100.00	100.00

UTAH.

Sandstone.—The following analysis of sandstone, quarried by the Kyune Graystone Company at their quarry at Jennings Spur, Utah County, was made by Mr. Herman Harms, chemist for the Nelden-Judson Drug Company, Salt Lake, Utah:

Analysis of sandstone quarried at Jennings Spur, Utah County.

	Per cent.
Silica, SiO_2	83.64
Iron oxide.....	1.96
Alumina, Al_2O_3.....	.46
Calcium carbonate, CaCO_3	8.50
Magnesium oxide, MgO}.....	.70
Water and volatile matter.....	3.22
Loss in analysis.....	1.62
Total	100.10

Specific gravity (practically), 2.5.

VERMONT.

Granite.—The following report on the "dark" and "medium" granite, quarried by Messrs. Wells, Lamson & Co. at their quarries at Barre, Washington County, was recently made by Dr. Wm. C. Day, of the analytical and testing laboratory of Swarthmore College, Swarthmore, Pennsylvania.¹

REPORT ON DARK AND MEDIUM GRANITE FROM BARRE, WASHINGTON COUNTY.

Chemical analysis of dark granite.

	Per cent.
Silica, SiO_2	69.56
Ferrie oxide, Fe_2O_3	2.65
Alumina, Al_2O_3	15.38
Manganese	Trace.
Lime, CaO	1.76
Magnesia, MgO	Trace.
Sodium oxide, Na_2O	5.38
Potassium oxide, K_2O	4.31
Loss on ignition, CO_2 , and moisture	1.02
Total	100.06

¹ For further detailed information see United States Geological Survey Report on Stone for 1897.

MINERAL RESOURCES.

Determinations of specific gravity.

DARK GRANITE.

	Grams.
Weight of granite	8.8061
Weight of water displaced	3.2856
Specific gravity found	2.672

Temperature of water, 22° C.

MEDIUM GRANITE.

Weight of granite	32.95745
Weight of water displaced	12.37680
Specific gravity found	2.662

Temperature of water, 20° C.

Determinations of absorption capacity.

DARK GRANITE.

	Grams.
Weight of granite after heating in air at 110° C. for six hours	49.9625
Weight of granite after boiling in water for three hours and wiping dry	50.0230
	.0605
Weight after heating again at 110° C. for six hours	49.9328

Per cent of water absorbed, 0.121.

MEDIUM GRANITE.

Weight of granite after heating in air at 110° C. for six hours	64.1723
Weight of granite after boiling in water for three hours and wiping dry	64.2549
	.0826
Weight after heating again at 110° C. for six hours	64.1534

Per cent of water absorbed, 0.129.

Crushing strength of the same granite, using the standard Timms Olsen testing machine.

DARK GRANITE.

[Crushing strain applied perpendicular to rift.]

No.	Size.	Area.	Broke at—	Crushing strength per square inch.
	<i>Inches.</i>	<i>Sq. inches.</i>	<i>Pounds.</i>	<i>Pounds.</i>
1	2 high by 2 by 2.02	4.04	71,870	17,790
2	2 high by 2.03 by 2.07	4.20	70,220	16,719

[Crushing strain applied parallel to rift.]

3	2 high by 2.06 by 2.04	4.20	83,820	19,957
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MEDIUM GRANITE.

[Crushing strain applied perpendicular to rift.]

1	2 high by 2 by 2.02	4.04	72,140	17,856
2	2 high by 2.02 by 2.04	4.12	61,670	14,968

[Crushing strain applied parallel to rift.]

3	2 high by 2 by 2.03	4.06	64,170	15,805
---	---------------------	------	--------	--------

Marble.—The following analysis of marble, quarried by the Columbian Marble Company at their quarry at Proctor, Rutland County, was made by Professor Penfield, of Yale University:

Analysis of marble quarried at Proctor, Rutland County.

	Per cent.
Carbonate of lime, CaCO_3	98.37
Carbonate of magnesia, MgCO_3 .....	.77
Carbonate of iron .....	.034
Manganese and aluminum oxides .....	.005
Siliceous matter insoluble in acids .....	.63
Organic matter .....	.08
Total	99.889

The coloring matter is pure carbon graphite, which is incapable of decomposition by atmospheric agents.

Slate.—The following table gives analyses of slate quarried in the slate belt of eastern New York and western Vermont:

Analyses of slate quarried in the slate belt

Name of firm quarrying stone.	Location of quarry.		Name of analyst.
	Town.	County and State.	
Rising & Nelson (quarry No. 2).	West Pawlet	Rutland, Vt.	Dr. W. F. Hillebrand, U. S. Geological Survey.
Griffith & Nathaniel	South Poultney	do	
William H. Hughes (quarry No. 10).	Brownell	do	
Auld & Conger	Wells	do	
Eureka Slate Quarries	Poultney	do	do
Valley Slate Co.	do	do	do
M. & J. McCarty	South Poultney	do	do
Francis & Sons	Castleton	do	do
Eureka Slate Quarries	Poultney	do	do
H. H. Mathews	Hampton	Washington, N. Y.	do
Empire Red Slate Co.	Granville	do	do
National Red Slate Co.	do	do	do
National Red Slate Co.	do	do	do
Empire Red Slate Co.	do	do	Mr. George Steiger, U. S. Geological Survey.
Fair Haven Red Slate Co.	East Whitehall	do	do
National Red Slate Co.	Granville	do	Dr. Hillebrand
American Black Slate Co.	Benson	Rutland, Vt.	do
Name of firm quarrying stone.	Location of quarry.		Name of analyst.
	Town.	County and State.	
Rising & Nelson (quarry No. 2).	West Pawlet	Rutland, Vt.	Dr. W. F. Hillebrand, U. S. Geological Survey.
Griffith & Nathaniel	South Poultney	do	
William H. Hughes (quarry No. 10).	Brownell	do	
Auld & Conger	Wells	do	
Eureka Slate Quarries	Poultney	do	do
Valley Slate Co.	do	do	do
M. & J. McCarty	South Poultney	do	do
Francis & Sons	Castleton	do	do
Eureka Slate Quarries	Poultney	do	do
H. H. Mathews	Hampton	Washington, N. Y.	do
Empire Red Slate Co.	Granville	do	do
National Red Slate Co.	do	do	do
National Red Slate Co.	do	do	do
Empire Red Slate Co.	do	do	Mr. George Steiger, U. S. Geological Survey.
Fair Haven Red Slate Co.	East Whitehall	do	do
National Red Slate Co.	Granville	do	Dr. Hillebrand
American Black Slate Co.	Benson	Rutland, Vt.	do

of eastern New York and western Vermont.

Substances determined.									
Silica, SiO ₂ .	Titanium dioxide, TiO ₂ .	Zirconia, ZrO ₂ .	Alumina, Al ₂ O ₃ .	Ferric oxide, Fe ₂ O ₃ .	Ferrous oxide, FeO.	Manga- nese oxide, MnO.	Nickel- ous oxide, NiO.	Cobalt- ous oxide, CoO.	Strontia, SrO.
Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
67.76	6.71	.....	14.12	0.81	4.71	0.19	Trace?	Trace?	.....
62.37	.74	.....	15.43	1.34	5.34	.22	Trace.	Trace.	.....
59.84	.74	.....	15.02	1.23	4.75	.34	Trace.	Trace.	.....
65.29	.....	.....	.....	.....	.....	.....	.....	.....	.....
59.27	.99	.....	18.81	1.12	6.58	.13	Trace?	Trace?	.....
58.48	1.02	Trace?	18.22	1.24	8.91	.67	Trace.	.....	Trace?
61.63	.68	.....	16.33	4.10	2.71	.09	Trace?	Trace?	.....
60.96	.80	Trace.	16.15	5.16	2.54	.97	Trace.	Trace.	.....
60.24	.92	Trace?	18.46	2.56	5.18	.97	Trace.	Trace.	.....
67.61	.56	.....	13.20	5.36	1.20	.10	Trace.	Trace.	.....
67.55	.58	.....	12.59	5.61	1.24	.19	Trace.	Trace.	.....
56.49	.48	.....	11.59	3.48	1.42	.30	Trace.	Trace.	.....
63.88	.47	.....	9.77	3.86	1.44	.21	Trace.	Trace.	.....
.....	.....	.....	.....	7.10	1.00	.....	.....	.....	.....
.....	.....	.....	.....	1.02	1.67	.....	.....	.....	.....
67.89	.49	.....	11.03	1.47	3.81	.16	Trace.	Trace.	.....
59.70	.79	.....	16.98	.52	4.88	.16	Trace?	Trace?	.....

Substances determined.									
Calcium oxide, CaO.	Baryta, BaO.	Mag- nesia, MgO.	Potas- sium oxide, K ₂ O.	Sodium oxide, Na ₂ O.	Lithium oxide, Li ₂ O.	Water below 110° C.	Water above 110° C.	Phos- phoric an- hydride, P ₂ O ₅ .	Carbon dioxide, CO ₂ .
Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
0.63	0.94	2.36	3.52	1.29	Strong tr.	0.23	2.98	0.07	0.40
.77	.67	3.14	4.20	1.14	Trace.	.34	3.71	.96	.87
2.20	.09	3.41	4.48	1.12	Strong tr.	.41	3.44	.09	2.98
.....
.42	.05	2.21	3.75	1.88	Trace.	.32	3.98	.11	.21
.56	.05	2.56	3.81	1.55	Trace.	.17	4.05	.10	.29
.50	.06	2.92	5.54	1.26	Strong tr.	.31	3.24	.16	.41
.71	.04	3.06	5.01	1.50	Trace.	.17	3.08	.23	.68
.33	.63	2.33	4.09	1.57	Strong tr.	.18	3.81	.11	.08
.11	.04	3.20	4.45	.67	Trace.	.45	2.97	.05	None.
.26	.31	3.27	4.13	.61	Trace.	.40	3.03	.19	.11
5.11	.06	6.43	3.77	.52	Strong tr.	.37	2.82	.09	7.42
3.53	.05	5.37	3.45	.20	Strong tr.	.27	2.48	.08	5.08
.....
1.43	.04	4.57	2.82	.77	Trace.	.36	3.21	.19	1.89
1.27	.08	2.23	3.77	1.35	Strong tr.	.90	3.82	.16	1.49

Analyses of slate quarried in the slate belt of eastern

Name of firm quarrying stone.	Location of quarry.		Name of analyst.
	Town.	County and State.	
Rising & Nelson (quarry No. 7).	West Pawlet	Rutland, Vt. .	Dr. W. F. Hillebrand, U. S. Geological Survey.
Griffith & Nathaniel	South Poultney	do	do
William H. Hughes (quarry No. 16).	Brownell	do	do
Auld & Conger	Wells	do	do
Eureka Slate Quarries	Poultney	do	do
Valley Slate Co	do	do	do
M. & J. McCarty	South Poultney	do	do
Francis & Sons	Castleton	do	do
Eureka Slate Quarries	Poultney	do	do
H. H. Mathews	Hampton	Washington, N. Y.	do
Empire Red Slate Co.	Granville	do	do
National Red Slate Co.	do	do	do
National Red Slate Co.	do	do	do
Empire Red Slate Co.	do	do	Mr. George Steiger, U. S. Geological Survey.
Fair Haven Red Slate Co. .	East Whitehall	do	do
National Red Slate Co.	Granville	do	Dr. Hillebrand
American Black Slate Co. .	Benson	Rutland, Vt. .	do

New York and western Vermont--Continued.

Substances determined.					Total sulphur included above, S.	Specific gravity.	Remarks.
Pyrite. FeS ₂ .	Sulphuric anhydride, SO ₂ .	Carbon, C.	Fluorine, Fl.	Total.			
<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>		
0.22	Trace.	None.	.....	100.07	0.12	.....	Sea-green slate.
.06	Trace.	Strong tr.	.....	99.80	.032	.....	Do.
.05	Trace.	Trace.	0.11	100.28	.024	2.7910	Do.
.....	.....	.....	.....	.....	.....	2.7627	Do.
.15	Trace.	None.	.....	99.98	.08	2.795	Unfading-green slate.
.13	.....	None.	.08	100.23	.07	.....	Do.
.04	Trace.	None.	.....	99.98	.02	2.8064	Purple slate.
None.	.....	None.	.....	100.22	.07	.....	Do.
.16	.....	None.	.....	100.12	.087	2.8053	Variegated slate.
.03	Trace.	None.	.....	100.60	.016	.....	Red slate.
.04	Trace.	None.	.....	100.02	.02	.....	Do.
.03	Trace.	None.	.....	100.38	.016	2.7839	Do.
Trace.	.....	None.	.....	100.14	.....	.....	Do.
.....	.....	.....	.....	.....	.....	2.8085	Do.
.....	.....	.....	.....	.....	.....	.....	Do.
.04	Trace.	None.	.....	100.08	.022	2.7171	Bright-green speckled slate.
1.18	Trace.	0.46	.....	100.05	.63	2.7748	Black slate.

For comparison the following well authenticated foreign analyses are inserted:

Analyses of foreign slates.

Kind of slate.	Location of quarry.	Name of analyst.	Substances determined.																Specific gravity.
			Silica, SiO ₂ .	Titanium oxide, TiO ₂ .	Alumina, Al ₂ O ₃ .	Ferric oxide, Fe ₂ O ₃ .	Ferrous oxide, FeO.	Calcium oxide, CaO.	Magnesia, MgO.	Potassium oxide, K ₂ O.	Sodium oxide, Na ₂ O.	Water.	Phosphoric anhydride, P ₂ O ₅ .	Carbon dioxide, CO ₂ .	Total.				
Delabole, gray roofing slate (two analyses).	Cannelford, Cornwall, England.	J. A. Phillips <i>a</i>	58.30	0.23	21.89	7.05	2.57	0.39	1.09	2.45	1.18	4.61	.....	.....	99.76	2.81	
Fumay:																			
Purple roofing slate.	Ardennes, France.....	A. Renard <i>b</i>	61.57	1.31	19.22	6.63	1.20	.22	2.00	3.63	.90	3.25	.....	.....	99.96		
Green roofing slate.	do.....	do.....	65.63	.94	20.29	2.72	.85	.19	1.54	3.81	.71	3.17	.....	.....	99.76		
La Richelle Quarry:																			
Blue-gray roofing slate.	Rimogne, Ardennes, France.	Klemente.....	61.43	.73	19.10	4.81	3.12	.31	2.29	3.24	.89	3.52	.....	.....	99.38		
Black slate.	Westphalia.....	H. von Dechen <i>d</i>	67.56	.....	12.23	2.87	6.99	.27	3.63	1.76	1.28	1.00	0.10	3.11	100.20			
Do.....	Frankenberg, Prussia.....	A. von Groddeck <i>e</i>	59.35	1.00	13.56	1.10	4.75	5.20	3.60	1.77	1.48	3.41	.31	4.45	99.98				
Bluish roofing slate.....	Near Wiggstadl, Mohrardorf, Silesia, Austria.	Nikolic <i>f</i>	55.06	.....	22.55	1.97	5.06	1.30	2.92	3.82	2.17	4.35	.....	.....	100.16	2.78
Glyn quarries, blue slate.	Llanberis, Wales, England.	Museum of Practical Geology, London. <i>g</i>	60.68	.59	21.20	5.68	.46	1.71	.88	2.64	2.99	2.88	.16	.67	100.04				

a London, Edinburgh, and Dublin Phil. Mag., 4th ser., No. 27, pp. 95-96, Feb., 1871. *b* Recherches sur la composition et la structure des phyllades ardennais, pub. by A. Renard; Bull. Mus. Roy. d'Hist. Nat. de Belgique, Vol. I, p. 239, 1882. *c* Pub. by A. Renard, op. cit. supra, p. 233. *d* Roth, Allgem. und Chem. Geol., II, pp. 586, 587, 1884. *e* Jahrb. pr. Geol. Landesanst., 1885-86; quoted in Roth, Allgem. Chem. Geol., II, pp. 586, 587. *f* Tschermaks Min. Mitth., 1871, p. 297; quoted by Roth, op. cit. supra, pp. 586, 589. *g* Geol. Mag., London, 1868, Vol. V, p. 123. *h* Carbon, C.

Slate.—The following tests of slate quarried by the American Black Slate Company at their quarries at Benson, Rutland County, were made by Dr. William C. Day, of the analytical and testing laboratory of Swarthmore College, Pennsylvania:

Transverse tests of slate quarried at Benson, Rutland County.

No. of spec-imen.	Distance between supports.	Width of slab.	Thick-ness of slab.	Broke at—	Modulus of rup-ture in pounds per square inch.	Remarks.
	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Pounds.</i>		
1	19.0	12.00	0.1925	171.25	10,975	
2	19.0	12.00	.1455	110.00	12,340	Deflection, 0.35 inches.
3	10.9	6.12	.1674	102.25	9,726	Deflection, 0.25 inches.

Specific gravity determinations of same slate.

No. 1.

	Grams.
Weight of pycnometer.....	26.3083
Weight of pycnometer and slate.....	33.4628
Weight of slate.....	7.1543
Weight of pycnometer, slate, and water.....	90.2068
Weight of pycnometer and water.....	85.6405
Weight of water displaced.....	2.5880
Temperature, 20.4° C.	
Specific gravity found = 2.764.	

No. 2.

	Grams.
Weight of slate in air.....	4.3861
Weight of slate in water.....	2.8120
Weight of water displaced.....	1.5741
Temperature, 20° C.	
Specific gravity found = 2.786.	

Absorptive capacity of same slate.

No. 1.

	Grams.
Weight of 6 pieces of slate in natural state.....	45.8621
Weight of 6 pieces of slate after drying six hours at 105° C.....	45.8067
Weight of 6 pieces of slate after drying again six hours at 105° C.....	45.7991
Weight of 6 pieces of slate after boiling in water six hours and wiping dry... 45.9184	
Gain in weight from absorbed water.....	.1193
	.0991
Absorptive capacity = $\frac{0.1193}{45.7991}$ = 00.26 per cent.	

No. 2.

[Same samples as in No. 1, but dried at 55° C. for twenty-four hours, instead of 105° C., and soaked in cold water forty-eight hours.]

	Grams.
Weight of sample after drying at 55° C.	45.8003
Weight of sample after soaking in water forty-eight hours and wiping dry, and allowing to stand in air a short time	45.9000
Absorptive capacity = $\frac{0.0997}{45.8003} = 0.22$ per cent.	

Corrodibility test of same slate.

	Grams.
Weight of sample taken	24.3815
Weight of sample after soaking in acid bath (2 per cent solution of equal weights of HCl and H ₂ SO ₄) twenty-four hours, then in water twenty-four hours, and finally drying in air one hour	24.2956
Weight of sample after soaking in fresh acid bath forty-eight hours, then in water twenty-four hours, and drying in air one hour	24.2010
Per cent of loss after twenty-four hours = 0.35.	
Per cent of loss after seventy-two hours = 0.74.	

The following analysis of the same slate was made by Dr. W. F. Hillebrand, of the chemical laboratory, United States Geological Survey:

Analysis of black slate quarried at Benson, Rutland County.

	Per cent.
Silica, SiO ₂	59.70
Titanium dioxide, TiO ₂ .....	.79
Alumina, Al ₂ O ₃	16.98
Ferric oxide, Fe ₂ O ₃ .....	.52
Ferrous oxide, FeO	4.88
Manganous oxide, MnO .....	.16
Nickelous oxide, NiO	Trace?
Cobaltous oxide, CoO	Trace?
Calcium oxide, CaO	1.27
Baryta, BaO .....	.08
Magnesia, MgO	3.23
Potassium oxide, K ₂ O	3.77
Sodium oxide, Na ₂ O	1.35
Lithium oxide, Li ₂ O	Strong tr.
Water below 110° C .....	.30
Water above 110° C	3.82
Phosphoric anhydride, P ₂ O ₅ .....	.16
Carbon dioxide, CO ₂	1.40
Pyrite, FeS ₂	1.18
Sulphuric anhydride, SO ₃	Trace.
Carbon, C .....	.46
Total	100.05
Total sulphur in above, S .....	.63
Specific gravity	2.7748

Limestone.—The following three analyses show the composition of lime made from limestone quarried by Mr. J. P. Rich at his quarry at Swanton, Franklin County. No. 1 was made by Mr. C. Sharpless, No. 2 by Mr. F. C. Robinson, and No. 3 by Mr. J. R. Chilton:

Analyses of lime made from limestone quarried at Swanton, Franklin County.

	No. 1.	No. 2.	No. 3.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Calcium oxide, CaO	98.47	99.29	98.84
Magnesium oxide, MgO	1.12	.46	.12
Ferrie oxide, Fe ₂ O ₃	Trace.		
Ferrous oxide, FeO .....		.12	
Carbon dioxide, CO ₂ .....	.45		1.02
Silica, SiO ₂	Trace.	.10	.02
Aluminum and manganese		Trace.	
Total	100.04	99.97	100.00

The following analysis of lime made from limestone quarried by Messrs. Follet Brothers at their quarry at North Pownal, Bennington County, was made by Mr. R. Schuppaus:

Analysis of lime made from limestone quarried at North Pownal, Bennington County.

	<i>Per cent.</i>
Calcium oxide, CaO	98.14
Magnesium oxide, MgO	1.40
Silica, SiO ₂ .....	.27
Alumina, Al ₂ O ₃ .....	.11
Ferrie oxide, Fe ₂ O ₃ .....	.08
Total	100.00

The following analysis of lime made from limestone quarried by the Brandon Lime and Marble Company at their quarry at Leicester Junction, Addison County, was made by Mr. C. T. Lee:

Analysis of lime made from limestone quarried at Leicester Junction, Addison County.

	<i>Per cent.</i>
Calcium oxide, CaO	98.262
Calcium carbonate, CaCO ₃ .....	.409
Magnesium oxide, MgO .....	.299
Silica, SiO ₂ .....	.383
Ferrie oxide, Fe ₂ O ₃ .....	.647
Total	100.000

The following analysis of lime made from limestone quarried by Mr. W. B. Fonda at his quarry at St. Albans, Franklin County, was made by Prof. F. C. Robinson, of Bowdoin College, Brunswick, Maine:

Analysis of lime made from limestone quarried at St. Albans, Franklin County.

	Per cent.
Calcium oxide, CaO	99.23
Insoluble matter.....	.14
Alumina, Al ₂ O ₃	Trace.
Iron.....	Trace.
Magnesium oxide, MgO.....	.60
Total	99.97

The following analysis was made by Mr. S. P. Sharples, State assayer for Massachusetts, of limestone quarried by Mr. L. H. Felton at his quarry at Highgate Springs, Franklin County, Vermont:

Analysis of limestone quarried at Highgate Springs, Franklin County.

	Per cent.
Calcium oxide, CaO	55.83
Magnesium oxide, MgO.....	Trace.
Oxides of iron and aluminum .....	.10
Silica, SiO ₂.....	.40
Carbon dioxide, CO ₂	43.65
Total.....	99.98

VIRGINIA.

Granite.—The following chemical analysis and tests of the granite quarried by the Petersburg Granite Quarrying Company at their quarries at Petersburg, Dinwiddie County, Virginia, were made by Messrs. Hunt and Clapp at their Pittsburg testing laboratory:

Analysis of granite quarried at Petersburg, Dinwiddie County.

	Per cent.
Silica, SiO_2	64.12
Alumina, Al_2O_3	20.91
Oxide of iron, Fe_2O_3	2.96
Lime, CaO	1.98
Magnesia, MgO} .....	.66
Sodium oxide, Na_2O	4.57
Potassium oxide, K_2O	4.82
Total	100.02

Constituent minerals of granite from Petersburg, Dinwiddie County.

	Per cent.
Mica	15.00
Feldspar	60.00
Quartz	25.00
Total	100.00

Test of 2-inch cube of granite from quarries at Petersburg, Dinwiddie County.

Original dimensions, 2 inches square.

Original area, 4 square inches.

Ultimate load, 100,400 pounds.

Crushing strength, 25,100 pounds per square inch.

The following tests of granite quarried by Mr. Peter Copeland at his quarry at Richmond, Henrico County, were made at the Watertown Arsenal:

Compression tests of granite quarried at Richmond, Henrico County.

No. of test.	Height.	Sectional area.	First crack.	Ultimate strength.	
				Total.	Per square inch.
	<i>Inches.</i>	<i>Sq. inches.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
1	1.90	4.00	93,000	102,080	25,520
2	1.90	4.00	103,000	114,500	28,625

Slate.—The following is an analysis of slate quarried by Messrs. John R. Williams & Co. at their quarries at Arvon, Buckingham County, by Dr. Henry Froehling:

Analysis of slate from Arvon, Buckingham County.

	Per cent.
Silica, SiO_2	60.65
Alumina, Al_2O_3	16.87
Ferric oxide, Fe_2O_3	7.79
Manganese	Trace.
Lime, CaO	1.91
Magnesia, MgO	2.39
Carbon dioxide, CO_2	Trace.
Sulphur, S .....	.69
Potash, K_2O	3.80
Soda, Na_2O	2.18
Water and organic matter	3.63
Total	99.91

The sample dried at 212°F .

Limestone.—The following analysis of limestone quarried by the Crozer Iron Company at their quarry at Buchanan, Botetourt County, was made by Mr. W. Walley Davis:

Analysis of limestone quarried at Buchanan, Botetourt County.

	Per cent.
Silica, SiO_2	0.104
Oxides of iron and aluminum .....	.518
Calcium carbonate, CaCO_3	61.640
Magnesium carbonate, MgCO_3	37.578
Total	99.840

The following analysis was made by Dr. Henry Froehling, Richmond, of limestone quarried by the Moore Lime Company at their quarry at Eagle Rock, Botetourt County:

Analysis of limestone quarried at Eagle Rock, Botetourt County.

	Per cent.
Calcium carbonate, CaCO_3	98.71
Magnesium carbonate, MgCO_3 .....	.65
Oxides of iron and aluminum, Fe_2O_3 and Al_2O_3 ..	.31
Silica, SiO_2 .....	.25
Total	99.92

WASHINGTON.

Sandstone.—The following compression tests of sandstone, known as Bellingham Bay stone, and quarried by Mr. Henry Roeder at his quarries at Chuckanut, Whatcom County, were made at the Watertown Arsenal under the direction of Maj. J. W. Reilly:

Tests of sandstone quarried at Chuckanut, Whatcom County.

[Compressed surfaces faced with plaster of paris to secure even bearings in the testing machine.]

Test No.	Dimensions.			Sectional area.	First crack.	Ultimate strength.	
	Height.	Compressed surface.				Total.	Per square inch.
	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Sq. in.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
7178	3.99	4.22	4.20	17.72	179,000	182,100	10,276
7179	4.09	4.13	4.20	17.35	183,000	221,900	12,790
7180	4.20	4.21	4.23	17.81	192,000	197,700	10,780

WEST VIRGINIA.

Limestone.—The following analysis of lime, made from limestone quarried by Messrs. G. C. and S. C. Ditto & Co. at their quarries at Marlowe, Berkeley County, was made by Mr. J. A. Ditto, Marlowe, West Virginia:

Analysis of lime made from limestone quarried at Marlowe, Berkeley County.

	Per cent.
Siliceous matter, insoluble	0.18
Calcium oxide, CaO	98.44
Magnesium oxide, MgO} .....	.98
Oxides of iron and aluminum, Fe_2O_3 and Al_2O_3 ..	.26
Carbon dioxide, CO_2 .....	.32
Total	100.18

The following analysis was made by Mr. J. Blodget Britton, of Warrenton, Virginia, of limestone quarried by Mr. D. Y. Huddleston at his quarry at Snow Flake, Greenbrier County, West Virginia:

Analysis of limestone quarried at Snow Flake, Greenbrier County.

	Per cent.
Calcium carbonate, CaCO_3	96.46
Magnesium carbonate, MgCO_3	1.11
Organic matter, loss on ignition.....	Trace.
Insoluble siliceous matter.....	.97
Sulphur.....	None.
Aluminum oxide, Al_2O_3	1.46
Phosphorus.....	None.
Total.....	100.00

WISCONSIN.

Granite.—The following analysis of granite, quarried by the Milwaukee Monument Company at their quarry in Waushara County, was made by Mr. A. S. Mitchell, chemist, of Milwaukee:

Analysis of granite quarried in Waushara County.

	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
Oxide of sodium, Na_2O	2.24
Oxide of potassium, K_2O	6.38
Total.....	99.83

The following analysis of granite, quarried by Mr. E. J. Nelson at his quarry at Berlin, Green Lake County, was made by Mr. Samuel Weidman, of Madison, Wisconsin:

Analysis of granite quarried at Berlin, Green Lake County.

	Per cent.
Silica, SiO_2	73.65
Alumina, Al_2O_3	11.19
Ferric oxide, Fe_2O_3	1.31
Ferrous oxide, FeO	3.25
Calcium oxide, CaO	2.78
Magnesium oxide, MgO} .....	.51
Potassium oxide, K_2O	1.86
Sodium oxide, Na_2O	3.74
Water, H_2O} .....	.44
Total	98.73

Sandstone.—The following analysis of the sandstone, quarried by the Prentice Brownstone Company at their quarries at Ashland, Ashland County, was made by Prof. C. F. Chandler, of Columbia University, New York City:

Analysis of sandstone quarried at Ashland, Ashland County.

	Per cent.
Silica, SiO_2	91.40
Ferric oxide, Fe_2O_3	2.00
Alumina, Al_2O_3	3.53
Lime, CaO} .....	.25
Magnesia, MgO	None.
Potash, K_2O	2.36
Soda, Na_2O} .....	.14
Sulphur	None.
Carbon dioxide, CO_2	None.
Moisture .....	.05
Total	99.73

The following is an analysis of quartz quarried by Messrs. Eichert & Werle at their quarry at Wausau, Marathon County. The analysis was made by Mr. Otto Boberg, chemist, of Eau Claire, Wisconsin:

Analysis of quartz quarried at Wausau, Marathon County.

	Per cent.
Silica, SiO_2	97.93
Ferric oxide, Fe_2O_3.....	.48
Magnesium oxide, MgO}.....	.91
Aluminum oxide, Al_2O_3.....	.06
Loss on ignition (moisture, etc.).....	.62
Total	100.00

Limestone.—The following analysis of limestone, quarried by Messrs. Nast Brothers, at their quarry at Knowles, Dodge County, was made by Prof. W. W. Daniells, of the University of Wisconsin:

Analysis of limestone quarried at Knowles, Dodge County.

	Per cent.
Calcium carbonate, CaCO_3	54.30
Magnesium carbonate, MgCO_3	45.32
Oxides of iron and aluminum .....	.24
Siliceous matter, insoluble.....	.28
Total	100.14

The following analysis was made by Mr. Gustave Bode, Milwaukee, Wisconsin, of limestone quarried by the Ormsby Lime Company at their quarry at Brillion, Calumet County:

Analysis of limestone quarried at Brillion, Calumet County.

	Per cent.
Calcium carbonate, CaCO_3	55.69
Magnesium carbonate, MgCO_3	43.96
Silica, SiO_2.....	.59
Aluminum oxide, Al_2O_3.....	.36
Total	100.00

The following is an analysis of limestone, quarried by the Milwaukee Falls Lime Company at their quarry at Grafton, Ozaukee County:

Analysis of limestone quarried at Grafton, Ozaukee County.

	Per cent.
Calcium carbonate, CaCO_3	52.57
Magnesium carbonate, MgCO_3	45.34
Silica, SiO_2.....	.37
Oxides of iron and aluminum, Fe_2O_3 and Al_2O_3 ..	.92
Oxides of potassium and sodium, K_2O and Na_2O ..	.80
Insoluble.....	.62
Total.....	100.62

The following analysis of limestone, quarried by the Hamilton Lime and Stone Company at their quarries at Hamilton, Fond du Lac County, was made by Prof. W. W. Daniells:¹

Analysis of limestone quarried at Hamilton, Fond du Lac County.

	Per cent.
Calcium carbonate, CaCO_3	54.25
Magnesium carbonate, MgCO_3	44.48
Ferrie oxide, Fe_2O_3.....	.26
Alumina, Al_2O_3.....	.10
Siliceous matter, insoluble.....	.67
Water.....	.11
Total.....	99.87

The following analysis was made by Mr. George N. Prentiss, Milwaukee, Wisconsin, of limestone quarried by Messrs. Blair and Larson at their quarries at Lannon, Waukesha County:

Analysis of limestone quarried at Lannon, Waukesha County.

	Per cent.
Calcium carbonate, CaCO_3	52.29
Magnesium carbonate, MgCO_3	42.27
Oxides of iron and aluminum.....	1.68
Silica, SiO_2	3.96
Total.....	100.20

¹ For further detailed information see Vol. II, Geological Survey of Wisconsin, p. 345.

The following analysis of lime made from limestone, quarried by the Sheboygan Lime Works at their quarry at Sheboygan, Sheboygan County, was made by Mr. Gustave Bode, of Milwaukee, Wisconsin:

Analysis of lime made from limestone quarried at Sheboygan, Sheboygan County.

	Per cent.
Calcium oxide, CaO	55.49
Magnesium oxide, MgO	42.31
Carbon dioxide, CO ₂ .....	.64
Silica, SiO ₂ .....	.46
Oxides of iron and aluminum	1.10
Total	100.00

Prof. N. O. Whitney, College of Mechanics and Engineering, University of Wisconsin, reports that the limestone quarried by the Waukesha Stone and Quarry Company, at their quarries at Waukesha, Waukesha County, has a crushing strength of 8,880 pounds per square inch, and in three tests of transverse strength an average modulus of rupture of 2,379 pounds.

WYOMING.

Sandstone.—The United States Government report of mechanical test gives the sandstone quarried by Mr. James McPherson at his quarry at Rawlins, Carbon County, a crushing strength of 10,833 pounds per square inch.