BUILDING STONES.

MARBLE PROSPECTS IN THE CHIRICAHUA MOUNTAINS, ARIZONA.

By SIDNEY PAIGE.

INTRODUCTION.

The following report is the result of an investigation made at the request of the Supervising Architect of the Treasury, through the United States Geological Survey, the writer spending four days in the field during the latter part of December, 1908. Arrangements made by Mr. John G. Kerr, of Bowie, Ariz., the manager of the properties examined, served greatly to facilitate field movements and added much to the pleasure of the undertaking. For this cooperation grateful acknowledgment is here extended.

GEOGRAPHY AND TOPOGRAPHY.

The properties examined are situated in Cochise County, Ariz., in the Chiricahua Mountains, a range which trends in a general northwest-southeast direction. These mountains rise abruptly from desert valleys—the San Simon on the northeast and the Sulphur Springs on the southwest. (See fig. 24.)

The main line of the Southern Pacific Railroad passes about 12 miles from the north front of the range, and the El Paso and Southwestern Railroad passes about the same distance from the eastern front at a point where it begins to curve to the south. The properties examined may be described in two groups—first, those accessible from Bowie, Ariz., and located about 14 miles S. 22° E. from that town; second, those located about 18 miles N. 50° W. from Rodeo, N. Mex., a station on the El Paso and Southwestern Railroad.

The claims of the first group lie in a belt which stretches westward from Emigrant Canyon to a point several miles beyond old Fort Bowie; those of the second group lie near the head of Whitetail Canyon, a short distance south of Cochise Head. The Chiricahua Range and its northwestward continuation, the Dos Cabezas Mountains, rise abruptly from desert valleys. From an elevation of 3,750 feet at Bowie the valley slopes almost imperceptibly at first, and then at a

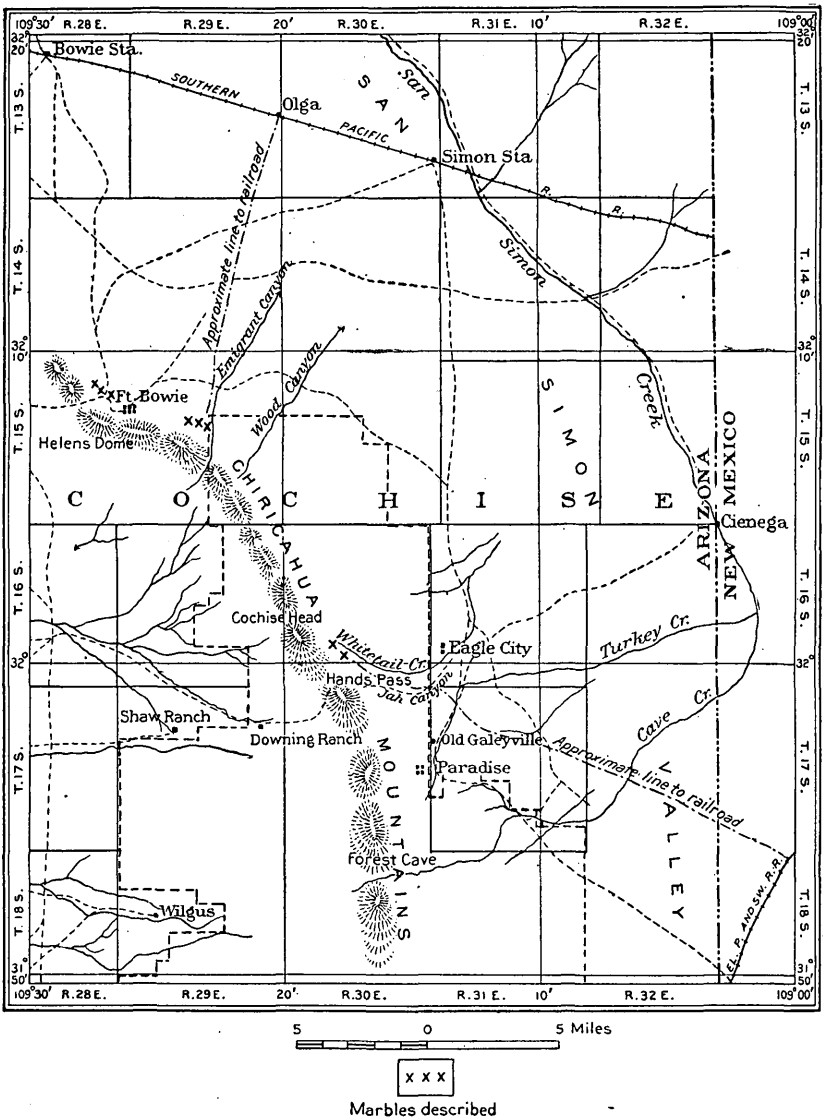

FIGURE 24.—Map showing location of marble prospects in Chiricahua Mountains, Arizona.

slightly steeper grade, upward to an elevation of about 4,400 feet at the base of the mountain scarp. From this point, on entering the range, one passes immediately to mountain topography—steep slopes, high stream gradients, and peaks that rise several thousand feet above the plains. All the drainage, flowing both south and north, is lost soon after leaving the mountain front in immense compound alluvial fans, such as characterize so many of these western deserts. The trend of the range is determined largely by the attitude of the rocks composing it. These are sedimentary beds, striking northwest and dipping to the southwest at an average angle of 45°. The range is narrow, as compared with its length, but its shape is modified to the south and north by intrusive igneous masses, and in very general terms that portion of the range lying near Fort Bowie owes its configuration to resistant beds of conglomerate and quartzite, through which cross-cutting streams have incised sharp canyons.

GEOLOGY.

GENERAL STATEMENT.

The rocks occupying the area under discussion are entirely of sedimentary origin, though igneous masses are known to exist at no great distance. They comprise, it is believed, strata of at least three geologic periods and possibly a fourth. The following notes are concerned chiefly with the rocks in the neighborhood of Fort Bowie, the marble prospects near by, and the strata near Cochise Head.

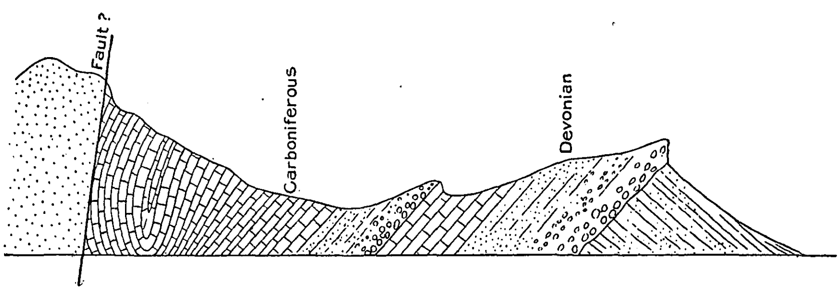

FIGURE 25.—Ideal section illustrating structural relations southeast of Fort Bowie, Ariz.

The Chiricahua Range trends northwest and southeast, and its northeast front is composed of stratified rocks with a like trend. A general section through the range a short distance southeast of Fort Bowie is shown in figure 25. The outer ridge presents two unconformable series, the older one dipping northwest at angles near 40° and the younger dipping southwest at angles varying between 30° and 60°. The unconformity between these two series is striking and is accentuated by the presence of a massive basal conglomerate which rests upon the eroded edges of the older beds and weathers into conspicuous cliffs.

Farther southwest a second and rather unusual unconformity may be observed. It occurs at the top of the younger of the two series just described and consists in an abrupt change of sediments. A fine-grained, massive blue limestone of considerable thickness is followed by a heavy conglomerate bed, which so far as could be observed was perfectly concordant in both strike and dip with the rocks that lay below it and whose contact with the limestone could be traced for miles. Another series of beds succeeding this conglomerate are terminated to the southwest by a second abrupt change, but here a heavy mass of quartzites takes the place of the limestone. This quartzite mountain mass, it is believed, owes its position to faulting, and the attitude of the beds composing it is not concordant with that of the limestone, the strike being N. 15° E. and the dip nearly vertical. (See fig. 25.)

STRATIGRAPHY.

The rocks of the lowest formation—that is, the one which forms the northeast range front—are apparently metamorphic sediments, and include possibly some volcanic rocks. They do not in the area observed form sharp outcrops, but in general present débris-covered slopes, which merge with the desert to the northeast. They are believed to represent the oldest rocks in the area studied.

The series unconformably overlying these rocks comprises a basal conglomerate, transition beds, fine quartzites, siliceous limestones, and limestones. The conglomerate, which is variable in thickness but probably does not exceed 25 feet in any place, consists of well-rounded pebbles ranging from an inch to a foot in diameter, an average probably being about 4 inches. The matrix of this conglomerate forms a minor part of the rock, and the pebbles are composed almost entirely of siliceous material, a condition which, it is believed, may largely be the result of secondary alteration. This conglomerate outcrops in a rough bluff on the outer ridge of the range.

Overlying the conglomerate is a thin series of beds intermediate in character between that rock and the quartzites which follow. The quartzites range in color through light yellows to dark brown, and are composed of well-banded, fine-grained, extremely hard siliceous material. The thickness of these beds is probably a thousand feet. They are followed by limestones with siliceous layers and nodules, which in turn grade into pure limestone.

The limestones are important because of their economic bearing. They are somewhat variable in character, the variation consisting largely in the presence or absence of siliceous material. At some horizons, however, the rock is fairly free from this impurity, and in general the beds are fine grained and dark blue in color, with a few narrow fossiliferous bands.

A second conglomerate (see fig. 25) introduces the next series of beds. It is of much the same nature as that already described, averages about 20 feet in thickness, and is marked generally by a bold outcrop. In some places it does not appear, though it may exist below the surface. This disappearance may possibly be due to an actual absence of the beds; if so, the origin of the conglomerate can be assigned to stream débris deposited upon a shallow-water limestone. The pebbles are well rounded and the absence of a matrix is generally remarkable. Pebbles which are now entirely silicified show markings peculiar to certain marbles from the overlying beds, to be described later. Quartzites, shales or their metamorphic equivalents, and limestones comprise the succeeding strata.

The last and fourth series, the unconformable quartzites, outcrop in a bold mountain mass. Their aggregate thickness is much greater and their bedding planes are less pronounced than those of the quartzites already described, but lithologically these rocks are very similar to the older quartzites.

Little is known concerning the age of the several series described above. E. T. Dumble[a] has shown that Carboniferous and Devonian rocks occur in the Chiricahua Mountains. Referring to the Carboniferous rocks, in the Swisshelm Mountains, he says: "In the Chiricahua Mountains on Cave Creek above Mr. Reed's house we found exposures of platy limestone resembling that at the base of these beds." And again: "North of this, between Cave Creek and Turkey Creek, the exposures of Carboniferous limestones are very satisfactory. They dip southwest from 30° to 45°; and the section is repeated by the occurrence of faults." "The rocks which underlie the Devonian in the Dragoon Mountains and which we found to occur both in the Mule and Chiricahua mountains were not differentiated."

It is assumed for the present, then, that the limestone series figured in the ideal section (see fig. 25) represents strata of Devonian and Carboniferous age.

STRUCTURE.

As the area which came under observation is small, conclusions regarding the broad structural features are presented with a certain degree of reluctance and can not be regarded as final. It is believed, however, that at least a sound basis for future investigations has been reached.

Figure 25 presents the structure of the series described above, in ideal section. Up to the point where a syncline is shown the beds are monoclinal and have a northwest trend, with dips varying between 30° and 60°. The evidence for synclinal structure follows. A view from the northwest of Limestone Mountain, a peak occupying a stratigraphic position corresponding to the uppermost limestones, shows clearly that its summit is the center of a syncline, and the strikes and dips observed on its slopes accord with this conclusion. These strikes and dips indicate, moreover, that the syncline pitches to the southeast, and it was noted that toward the northwest

[a] Notes on the geology of southeastern Arizona; Trans. Am. Inst. Min. Eng., vol. 31, 1902, p. 713.

the strata involved were in part cut out—that is, the base of the beds, or such part as was included in the fold, had been removed by erosion. One standing on the summit of Limestone Mountain and looking northwest may observe synclinal structure a short distance from the unconformable quartzite contact, and an overturning of the southern limb of the fold is strongly suggested. Both the summit of Limestone Mountain and the rocks near the quartzite contact are characterized by a lack of bedding and a general crushed condition, phenomena characteristic of a synclinal axis. Finally, to the southeast were noted minor folds that complicate the structure in the vicinity of the marble prospects.

Quartzite Mountain, it is believed, owes its elevated position to faulting, probably contemporaneous with the folding and due to similar forces of compression. The fault plane, so far as could be judged, is curving and more or less nearly vertical.

METAMORPHISM.

Two effects of metamorphic processes are noteworthy within this area. Marble zones have been formed in the limestone strata, and silicification on a large scale is believed to have taken place. As the latter process does not concern the present report it will be discussed very briefly. It was noted that certain limestone beds in the lower series disappeared along the strike in a southeasterly direction, but that in that vicinity there were some entirely silicified bowlders marked in patterns precisely like those in the marble zones, a fact which suggests that silicified beds now represent these limestones. As evidence of faulting to account for the disappearance of the limestones did not appear, it is presumed that owing to the presence of igneous masses, which exist in the near vicinity, or through the agency of circulating waters acting during the period in which these rocks were deeply buried, a siliceous replacement of the marble and limestones of the lower series has taken place on a large scale.

The marble zones in the limestone are of wide extent. Their formation may be adequately accounted for as resulting from the effects of heat, either developed during the process of folding or emanating from intrusive masses. A combination of the two causes affords the most plausible explanation. The process resulted in a complete recrystallization of the rock, a change of color, generally from blue to white or pink, and a segregation of the carbonaceous matter in fine markings, which add to the beauty of the stone. The zones are of the nature of more or less extended beds within the limestone strata, and as they owe their existence to metamorphic forces they are not confined to any one horizon. Both their quality and their extent are variable, but in general they conform in dip and strike with the limestones.

MARBLE.

INTRODUCTION.

The marble prospects visited by the writer may conveniently be grouped under three heads, which will be described separately. They may be called the western marbles—those west of Fort Bowie, in Devonian rocks; the central marbles—those near the head of McIntosh Canyon (a tributary of Emigrant Canyon), in Carboniferous rocks; and the southern marbles—those at the head of Whitetail Canyon, near Cochise Head, also believed to occur in Carboniferous rocks.

WESTERN MARBLES.

Distribution.—The western marbles occupy a stratigraphic position near the top of the Devonian and extend northwestward from Fort Bowie in a more or less regular band for several miles. The portion examined by the writer is almost wholly within one holding, the Sienna group of claims, a tract of 160 acres. The ledge varies in width between 50 and 75 feet and dips to the southwest at about 60°. The topography is rugged and the outcrop is continuously exposed on hillsides and ridges and in valleys.

Composition and appearance.—No analyses are at hand, but the rock is probably a nearly pure carbonate of lime, with medium-grained, crystalline-granular structure, and for the most part of a pure white color with pinkish tones. Impurities in the form of narrow seams of red iron oxide are abundant but present a very beautiful appearance and if the rock is used for decorative purposes might under suitable conditions greatly enhance its value. On the borders of the ledge the colors range through grays to blues. The lack of silica bands is noteworthy.

Jointing.—Unfortunately, the greater part of this exposure reveals extensive jointing. The joints vary greatly in their direction, and no regularity that might aid in the extraction of the material was observed. In a few localities these joints are on the whole less pronounced and more solid rock might be expected with increasing depth, but a number of prospect pits blasted out along the outcrop all reveal a similar condition of severe fracturing.

In view of the possibilities of a diminution in the number of joints in depth and of the beauty of the stone for ornamental purposes, the ledge deserves prospecting. It is possible that at a depth of perhaps 30 feet, even though the seams should still occur, commercial slabs might be obtained by careful handling. Considerable work with a core drill is needed to prove the commercial value of these deposits.

CENTRAL MARBLES.

Distribution.—The central marble properties are comprised in two 160-acre tracts, the Pavonazzo and Pentelicus groups of claims. The two tracts, joined end to end, have a northwest-southeast trend and extend from a tributary of Emigrant Canyon over a divide into the valley of a second stream. Marble exists in this general area at localities other than within these boundaries, but the following remarks refer especially to these two groups.

Marble in ledges of varying widths is present for practically the entire length of the two claims, a distance of about 1¾ miles, and occurs as bands and lenses in a fine-grained blue limestone. The ledges accord in strike and dip with the limestone—that is, they trend northwest and have steep dips to the north, a dip at variance with the beds farther northwest and due to some structural feature not at present determined.

Though synclinal structure is known to exist in the near vicinity, a detailed study of the beds near the marble leads to the conclusion that the deposits are of such thicknesses as to insure sufficient material for many years, provided that in depth metamorphism has been equally effective in altering the limestone to its condition shown at the surface. The length and width of the outcrop and the attitude of the beds seem to justify the assumption of a continuance of the surface conditions for considerable depths.

Composition and character.—An analysis of the marble from the Pavonazzo claim shows the stone to be a practically pure carbonate of lime, containing 99.98 per cent of $CaCO_3$.[a] All evidence of original bedding has disappeared from the stone, which is now a massive, even, crystalline-granular, medium-grained aggregate of calcite crystals, the separate crystals being plainly visible with the unaided eye. The dominant color is white, or pinkish or grayish white, with irregular black markings. Gray, dove-colored, and blue varieties may also be seen, and areas are found where pure-white material can be extracted. As compared with eastern marbles, many specimens of which were examined in the collection of the United States National Museum, the black marking is generally more clear cut and finer and the base clearer. A comparison with the only two available specimens of the Italian Pavonazzo marble shows that in the Arizona rock the base is crystalline as opposed to waxy, the markings are not so perfectly black and clear cut, and the general appearance is not so rich. The rock is, however, handsome, and individual taste must be used in comparisons. The availability of several varieties may be considered a distinct advantage in commercial exploitation.

[a] Oral statement by Mr. Kerr.

It has been pointed out that the marble zones occur as lentils or beds in limestone strata, and as many of these strata are characterized by bands of siliceous material, the marbles likewise contain them. These siliceous bands are variable in length, thickness, and number. They may completely destroy a body of marble or they may be so scattered as to be of no appreciable harm. All gradations exist between these conditions, but the bands have in common one desirable property—they accord with the strata in strike and dip. The commercial availability of a piece of marble, therefore, depends on the presence or absence of these bands, and the number that may be considered permissible must be determined by future developments. As shown elsewhere, a number of localities are entirely free from them. Other than the siliceous bands, no deleterious constituents of the rock were observed, pyrite being noteworthy by its absence.

Weathering.—The rock has excellent weathering qualities in the climate of Arizona. For the most part the merest film has formed on the surface, and when this is broken through the fresh, hard white stone is revealed. On a block that was blasted from a prospect pit and had lain two years and four months exposed to the elements no effects of weathering could be noted with the naked eye.

Jointing.—Observations on jointing are by their nature superficial, and must be accepted with an understanding of the meager data on which they are based—generally surface indications. Like the siliceous bands already mentioned, the joints vary in abundance and distribution, locally being so numerous as to give little hope of commercial stone, but elsewhere being so nearly lacking that a good body of rock is assured. Evidence gathered in the only two openings made on these properties indicated, in a measure, that many surface joints would give out in depth. At other places the peculiar rounded form and great solidity of the weathered blocks suggested a shallow depth for many joints. No definite system could be established, though locally the parallelism of the joints may aid in quarrying. This matter will be again mentioned in the descriptions of localities.

The presence of siliceous bands is the only obstacle to the easy extraction of the marble. As channeling machines would be used, the regularity in strike and dip of such bands, if they existed in the area selected, would assure at least one direction of unobstructed cutting. They in a measure determine the manner of quarrying, but should not seriously interfere with exploitation if wide bands of pure marble are present between them. The writer is informed that the stone works freely.

Special localities.—The localities of greatest promise on the Pavonazzo and Pentelicus claims are situated on a nearly continuous body of marble, more or less of which is available. This area, beginning near the southeast end of the Pavonazzo claim, in the sharply incised valley of a small stream, extends up the steep slopes of a hillside, over a divide, and down the slopes on the southeast side. Within this area several bodies of marble exist, quite or nearly free from silica and in some places entirely free from joints. It should be noted that there is practically no overburden and that the cutting away of the rather sparse underbrush will permit an immediate attack on the solid stone, though naturally the upper cuts would not be used.

On the Pavonazzo claim a ledge of marble 75 feet thick, about 250 feet long, and generally free from silica may be seen. The rock is white and pinkish white with black markings, but some grays are also present. Weathering reveals more or less jointing, north and south, N. 30° E., and in other directions; but the writer believes that much of this jointing will disappear in depth, or at least that it will not interfere with the obtaining of commercial slabs. From this locality, by blasting, which naturally shatters the rock and would not be employed in quarrying, slabs over 6 feet long and 2 feet wide were obtained. Six slabs 5 by 2 feet were also taken out. The various markings on these slabs lend themselves readily to the designer's skill and beautiful effects in matching have been produced.

To the southeast, up the steep hillside, a fine ledge of marble may be observed. Within it at two localities, and perhaps more, a quarry floor could be opened. A thickness of 30 to 50 feet and a length of at least 75 feet are conservative figures for bodies of marble practically solid and free from silica in this ledge; and there can be no doubt as to their continuance in depth, for the outcrop of the ledge climbs a steep slope. It is reasonable to suppose that as depth is attained the linear extent of available commercial rock will be considerably increased. The character of the stone is essentially the same as that of the ledge just described.

The Pentelicus claim comprises, perhaps, the best prospects in this region. The marble here has taken more the form of an irregular mass, not being confined between regular walls of limestone. For a width of about 300 feet and a length of at least 500 feet, it presents several areas where quarries might be opened. Two areas, selected because of their general freedom from silica in bands, were noted where a floor 100 by 100 feet might be started, and though silica is present, it should not interfere with the extraction of blocks of great size, larger than are usually demanded. As the brush which covers this outcrop has not been removed, it is reasonable to suppose that other equally good areas will be found. Jointing is not pronounced in the two areas mentioned, and probably grows less with depth. An opening made by blasting has revealed a white crystalline-granular marble with rich pink tints.

Considering the fact that all the above-described outcrops are in no sense other than surface showings, the prospect is very encouraging and there is no reason to believe that the deposits will not have ample depth, if the metamorphism which has converted the limestone to marble at the surface has extended throughout the mass of the rock. As has been pointed out, the marble zones are purely metamorphic developments in limestone strata, and structural evidence must be used with extreme caution as a basis for predicting continuity in depth; yet, in view of the length and breadth of the mass, it is reasonable and conservative to predict a large quantity of material. Other marble ledges were seen in the immediately adjacent region and two of them at least may develop into commercial properties.

In briefly summarizing, the following points should be noted:

The deposits are undeveloped surface showings and as such are promising. A minimum amount of dead work need be done; solid rock is at the surface in some localities and but a few cuts will be necessary to reach commercial stone. In other places where jointing is more pronounced, the valuable rock lies at greater depth. Silica bands are largely absent from a number of areas that might make quarry floors. In other areas large blocks for sawing could be taken out by cutting between the bands of silica. It must be said, however, that though silica in bands is the only detrimental material in the stone, it is one which must be thoughtfully considered, if the deposits are to be profitable.

Utilization.—The above-described marbles will probably be used for interior decorative purposes. It is believed that blocks of commercial size can be extracted, sawed into slabs, turned into columns, or fashioned to meet any of the general needs of architectural work.

Transportation.—The Pentelicus claim, on which development will probably be first undertaken, is 14½ miles from Olga, a point on the Southern Pacific Railroad 9 miles east of Bowie. About 3½ miles of this distance is within the mountains, and in building a road for a traction engine the ordinary difficulties encountered in such country will have to be overcome. The 11-mile stretch from the base of the mountains to the railroad presents no difficulties other than those attached to the building of a road on an even down grade over an alluvial fan. The mountain work from the Pavonazzo claim will be a little more difficult, but the problems involved are essentially the same. The writer is informed that the rates to eastern centers, via the Gulf, are sufficiently low to make the industry profitable.

SOUTHERN MARBLES.

Location.—The marble of the southern area occurs near the head of Whitetail Canyon, on its southwest side. The property examined is called the Cochise marble placer and is accessible from the El Paso and Southwestern Railroad. It lies about 18 miles N. 50° W. from Rodeo, N. Mex., and about 5 miles northwest of Paradise, Ariz. The ledge can be traced for a mile and occurs as a band in a series of northwest-southeast trending Carboniferous (?) limestones.

Composition and appearance.—No analyses of the rock are at hand, but its manner of weathering and appearance indicate that it is probably a nearly pure calcium carbonate. It is a coarsely crystalline-granular white marble, without markings. On the surface when broken and in a pit opened by drilling and blasting the material revealed is a dead white.

Limonite stains were seen in the open cut, the streaks running parallel to the strike, but only two were observed within a vertical distance of about 15 feet. Silica, in bands, occurs in a similar manner to that already described. At the base of the ledge about 100 feet is entirely free from this impurity. A narrow band of silica is then succeeded by about 50 or 60 feet of clean stone, and from this point up silica is rather abundant. With slight variations this condition exists throughout the claim.

Weathering.—The rock shows slightly more decomposition at the surface than does that of the Pavonazzo and Pentelicus claims. Though this condition seems variable, probably on the removal of 20 or 30 feet of rock the stone will be seen at its best, lacking what might be characterized as a slightly dull appearance in the surface rock.

Jointing.—The deposit is remarkably solid and generally free from such joints as would materially affect its extraction.

Utilization.—The ledge outcrops on a hillside above the gulch and, though no appreciable overburden exists, probably 20 or 30 feet will have to be removed before the best stone is reached. If its weathering qualities, of which no tests are available, prove satisfactory, the material should make excellent building stone. Its quality as a decorative material must be decided by samples submitted to those desiring to use the stone. The quantity is assured so far as surface conditions and geologic structure can be used as criteria, and blocks of any size may be extracted.

Transportation.—A road for a traction or other engine would have to be built a distance of 18 miles to reach the nearest railroad.

TESTS.

The following tests were made at the structural-materials laboratories of the Geological Survey at St. Louis:

Results of tests on marble from the Arizona marble quarry, Bowie, Cochise County, Ariz.

No. of test piece.	Compression test.					Weight ratio of absorption.		
	Position in machine.	Lateral dimensions (inches).	Height (inches).	Ultimate strength (pounds per square inch).	Modulus of elasticity.	30 minutes.	24 hours.	48 hours.
1	On bed	2.06 by 2.06	2.07	10,430	2,100,000	0.0010	0.0010	0.0010
2	...do	2.06 by 2.07	2.08	11,500	2,175,000	.0011	.0011	.0011
3	...do	2.07 by 2.07	2.07	12,000	2,350,000	.0011	.0011	.0011
Average				11,310	2,208,000	.0011	.0011	.0011
4	On edge	2.06 by 2.08	2.08	8,480	1,500,000	.0010	.0010	.0010
5	...do	2.11 by 2.07	2.09	10,000	1,775,000	.0011	.0011	.0011
6	...do	2.09 by 2.11	2.10	9,400	2,450,000	.0010	.0010	.0010
Average				9,290	1,908,000	.0010	.0010	.0010
General average				10,300	2,058,000	.0011	.0011	.0011

No. of test piece.	Volume ratio of absorption.			Absolute pore space=1−density.	True specific gravity.	Apparent specific gravity.	Weight per cubic foot (pounds).
	30 minutes.	24 hours.	48 hours.				
1	0.0027	0.0027	0.0027		2.721	2.709	168.91
2	.0030	.0030	.0030		2.719	2.707	168.80
3	.0029	.0029	.0029		(a)	2.711	169.05
Average	.0029	.0029	.0029			2.709	168.92
4	.0028	.0028	.0028		(a)	2.708	168.86
5	.0030	.0030	.0030		(a)	2.708	168.86
6	.0027	.0027	.0027		(a)	2.710	168.99
Average	.0028	.0028	.0028			2.709	168.90
General average	.0029	.0029	.0029	0.0041	2.720	2.709	168.91

[a] Only 2 tests made.

SURVEY PUBLICATIONS ON BUILDING STONE AND ROAD METAL.

The following list comprises the more important publications on building stone and road metal by the United States Geological Survey. These publications, except those to which a price is affixed, can be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publications may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. The annual volumes on Mineral Resources of the United States contain not only statistics of stone production, but occasional discussions of available stone resources in various parts of the country. Many of the Survey's geologic folios also contain notes on stone resources that may be of local importance.

ALDEN, W. C. The stone industry in the vicinity of Chicago, Ill. In Bulletin No. 213, pp. 357–360. 1903. 25c.

BAIN, H. F. Notes on Iowa building stones. In Sixteenth Ann. Rept., pt. 4, pp. 500–503. 1895.

BASTIN, E. S. (See Leighton, Henry, and Bastin, E. S.)

BURCHARD, E. F. Concrete materials produced in the Chicago district. In Bulletin No. 340, pp. 383–410. 1908.

COONS, A. T. Stone. In Mineral Resources U. S. for 1907, pt. 2, pp. 563–605. 1908.

DALE, T. N. The slate belt of eastern New York and western Vermont. In Nineteenth Ann. Rept., pt. 3, pp. 153–200. 1899. $2.25.

——— The slate industry of Slatington, Pa., and Martinsburg, W. Va. In Bulletin No. 213, pp. 361–364. 1903. 25c.

——— Notes on Arkansas roofing slates. In Bulletin No. 225, pp. 414–416. 1904. 35c.

——— Slate investigations during 1904. In Bulletin No. 260, pp. 486–488. 1905. 40c.

——— Note on a new variety of Maine slate. In Bulletin No. 285, pp. 449–450. 1906. 60c.

——— Recent work on New England granites. In Bulletin No. 315, pp. 356–359. 1907.

——— The granites of Maine. Bulletin No. 313. 202 pp. 1907.

——— The chief commercial granites of Massachusetts, New Hampshire, and Rhode Island. Bulletin No. 354. 228 pp. 1908.

——— The granites of Vermont. (In preparation.)

DALE, T. N., and others. Slate deposits and slate industry of the United States. Bulletin No. 275. 154 pp. 1906. 15c.

Darton, N. H. Marble of White Pine County, Nev., near Gandy, Utah. In Bulletin No. 340, pp. 377–380. 1908.

——— Structural materials near Portland, Oreg., and Seattle and Tacoma, Wash. Bulletin No. 387. — pp. 1909.

Diller, J. S. Limestone of the Redding district, California. In Bulletin No. 213, p. 365. 1903. 25c.

Eckel, E. C. Slate deposits of California and Utah. In Bulletin No. 225, pp. 417–422. 1904. 35c.

Hillebrand, W. F. Chemical notes on the composition of the roofing slates of eastern New York and western Vermont. In Nineteenth Ann. Rept., pt. 3, pp. 301–305. 1899. $2.25.

Hopkins, T. C. The sandstones of western Indiana. In Seventeenth Ann. Rept., pt. 3, pp. 780–787. 1896.

——— Brownstones of Pennsylvania. In Eighteenth Ann. Rept., pt. 5, pp. 1025–1043. 1897.

Hopkins, T. C., and Siebenthal, C. E. The Bedford oolitic limestone of Indiana. In Eighteenth Ann. Rept., pt. 5, pp. 1050–1057. 1897.

Humphrey, R. L. The fire-resistive properties of various building materials. Bulletin No. 370. 99 pp. 1909.

Keith, A. Tennessee marbles. In Bulletin No. 213, pp. 366–370. 1903. 25c.

Leighton, Henry, and Bastin, E. S. Road materials of southern and eastern Maine. Bulletin No. 33, Office of Public Roads, Department of Agriculture. 1908. (May be obtained from Department of Agriculture.)

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