STRUCTURAL MATERIALS.

GENERAL.

FIELD INVESTIGATIONS OF STRUCTURAL MATERIALS.

By Ernest F. Burchard.

In connection with the work of testing structural materials for the use of the Government at the laboratories of the United States Geological Survey at St. Louis, Mo., from September, 1904, to April, 1909, and since then at Pittsburg, Pa., large quantities of sand, gravel, and crushed stone have been needed from time to time, besides samples of building stone, clays, and other quarry products. In many instances it has been necessary to obtain single samples of sand, gravel, or crushed stone in lots of 1 to 3 carloads.

For obvious reasons all these collections have had to be made by a Survey representative. As the work progressed it was found essential that numerous geologic data should be gathered regarding the material collected, in order that it might be properly classified as to character, source, geologic age, etc.; that it might be rated according to quantity available, nearness to transportation lines, approximate costs, suitability for special purposes, etc.; and that notes might be taken regarding undeveloped deposits of possible value. Furthermore, it was desired that the selection of materials for tests should be made broadly, in order to obtain, first, representative types of material, and later, if possible, typical materials of the more important building centers in the United States. In order to secure a certain degree of uniformity in this work and economy of effort and expense, it was decided to have as much of the sampling as was practicable done by a geologist whose regular field trips could be combined conveniently with those necessary for obtaining materials for the laboratory. During parts of the last three years several geologists, including the writer, have been engaged in field work of this sort.

The results of the field and laboratory investigations of structural materials are intended primarily for the information of those departments of the Government that are engaged in construction work, namely, the office of the Supervising Architect of the Treasury Department; the War Department, which has charge of the river and harbor improvements and the building of fortifications and barracks; the Isthmian Canal Commission; the Reclamation Service, under the Department of the Interior; and the Navy Department, under which is the Bureau of Yards and Docks. The field and test data have been made available to these departments, although comparatively little of the information has yet been published. However, when fairly complete information has been obtained that is thought to be of general interest it has been compiled and published. The principal reports along these lines are given in the bibliographies at the ends of the chapters on stone, cement and concrete, and other structural materials in this bulletin.

Before the fiscal year 1909–10 the making of general typical collections and of special areal studies was the principal work undertaken. In the spring of 1909 a request was received by the Director of the Survey, through the Secretary of the Interior, from the Secretary of the Treasury, accompanied by a list of about 380 cities in which Congress had authorized the construction of new federal buildings and extensions on which work would be in progress in various stages within the next three or four years. This work will involve an expenditure of more than $50,000,000. The following quotations from this request are therefore of interest here:

> It will be in the interest of the Government to have the Geological Survey furnish this Department with information as to the character and extent of the sands, gravels, stone, and other materials suitable for work in concrete construction; sands for mortars; stone for masonry work; brick, terra cotta, hollow tile, and other structural materials that may be suitable and available for use in the construction of these buildings within easy reach of each of the localities named in this list. Exact and thorough data of this kind will not only be of great service in connection with the construction of the buildings in question, but also in the preliminary planning of them.
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> Reports should be submitted to the Supervising Architect's office from time to time, as rapidly as any part of this work can be completed or definite results obtained, without awaiting publication, in order that this information may be available for use in the planning and construction of public buildings already authorized.

In view of the urgency of this request, it became necessary to make this work a special order of business, rather than incidental to other field trips. Therefore, during the last half of 1909 part of the time of six geologists and all the time of the writer was spent on this work, with the result that about 85 per cent of the 380 specified localities, including all the urgent cases, were visited, and a preliminary field report on each one was prepared and sent to the Supervising Architect.

At the outset it was planned that there should be uniformity in the reports, and therefore they were prepared mostly according to the following outline, care being taken that only data of a practical character should be given:

Structural materials investigated for use in federal buildings.

I. Stone:
- A. Dimension stone for exterior—
  - a. Foundations.
  - b. Walls.
  - c. Sills and trim.
- B. Ornamental stone for interior (marble, serpentine, onyx, etc.).
- C. Slate for roofing, sanitary fixtures, etc.

II. Material for concrete:
- A. Sand.
- B. Gravel.
- C. Crushed stone, slag, cinder, shell, etc.
- D. Cement (Portland, natural, hydraulic, etc.).

III. Clay products:
- A. Brick—
  - a. Common.
  - b. Front (pressed, rough, fire-faced, etc.).
- B. Tile—
  - a. Roofing.
  - b. Hollow building tile or block.

IV. Materials for mortars and plasters:
- A. Lime—
  - a. Quick.
  - b. Hydrated.
- B. Gypsum wall plasters.
- C. Sand.

Necessarily the work was done very rapidly, and the reports were written not for the use of geologists, but rather for that of persons who may not have had training in geology. The points of interest to the geologist, however, such as the nature, extent, quality (as to uniformity, durability, color, etc.), location (as to means of handling and transportation), structure, and geologic relations in general that affected the use of materials, were borne in mind throughout the series of reports. All except two of the reports ranged in length from 1 to 10 or 12 typewritten pages, but averaged less than 5 pages.

In these field studies the endeavor was to relieve the laboratory of all the work possible and to give the Supervising Architect a definite opinion as to the value and availability of a material, backed up by a detailed description of it and the results of simple field tests. In addition, use was made of any authentic test data in possession of the producer or contained in state geological survey reports. The common points considered with regard to stone, gravel, clay, gypsum, etc., were noted on special forms in loose-leaf books. Many special details had to be considered with regard to the various materials, and for brick and other clay products notes of a special form were kept regarding the processes of manufacture. Sands were subjected to qualitative tests for the presence of lime, alkali, clay, magnetite, quicksand, and silt. Granularmetric analyses were made and the material was critically examined under the field lens.

A knowledge of the Supervising Architect's general specifications was requisite, and after a little practice the geologist was able to tell in most cases, after a careful investigation, whether a sand, gravel, stone, or brick would fulfill these specifications or not.

If the question should be asked, of what direct advantage are these reports to the Supervising Architect or to federal construction work in general, the answer may be summarized as follows:

1. Attention is called to materials of merit which, owing to their proximity to the building site, should be obtainable at lower prices than similar materials from long distances.

2. Attention is called to little-developed and hitherto comparatively unknown materials that may possess special merit for certain kinds of work.

3. Warning is issued against the use of materials that are not suitable yet that are commonly used in certain localities.

4. Warning is issued against the acceptance of materials from deposits which may be of good quality but of insufficient quantity.

5. Warning is issued against the acceptance of materials from deposits which may afford excellent material in small samples, but whose quality in adequate quantities is irregular and inferior.

6. Data regarding local costs and freight rates are obtained on small and large lots of all materials shipped into the locality, such as cement, stone, sand, wall plasters, etc., thus affording aid toward preparing specifications for new buildings.

7. Some attention was paid to the proposed federal building sites, with reference to character and condition of the ground on which foundations would have to rest and with reference to the smoke conditions.

In addition to the results of this work as related to the Government, its relation to the country at large may be mentioned. When little-known but meritorious materials are thus brought to the attention of the Supervising Architect, and incidentally to that of the public, as they doubtless will be brought later by use in federal buildings and by published reports, the efficient use of important natural resources is encouraged. In many instances during the past field season, materials that would probably otherwise have been passed unnoticed have been brought to the attention of the Supervising Architect. Many such instances might be noted, but the following are fair samples showing the range of such materials covered.

1. Large and sound glacial bowlders that occur in great abundance in the vicinity of Minot, N. Dak., a region otherwise devoid of stone. These bowlders can be split and trimmed into handsome, massive dimension stones.

2. The "chats" or tailings from the concentrating mills in the Plattville, Wis., zinc district, from the copper smelter at Great Falls, Mont., etc. These chats make an excellent aggregate for both plain and reinforced concrete work, and the tailings from the Great Falls smelter make good sand for mortar and brick.

3. Sandstones used locally at Carrollton and Warrensburg, Mo., and Big Stone Gap, Va.

4. Oolitic limestone at Bowling Green, Ky.

5. Subcrystalline limestone at Batesville, Ark., Frankfort, Ky., and Harriman, Tenn.

6. Shale near Mansfield, Ohio, suitable for brick making.

7. Loam at various points in the Mississippi embayment in Arkansas, Mississippi, and Tennessee, suitable for the manufacture of brick.

8. Sand and gravel from points on Arkansas River in Kansas and Oklahoma, very similar in quality to the well-known Kaw River sand.

Besides the work outlined above, there have been carried on at times during the past year at the laboratories of the Survey, in Pittsburg and Washington, special investigations of such subjects as the manufacture and the hydration of lime and studies of Keene cement and wall plasters, tending toward the formulation of standard specifications for these materials in government construction work. Here again the services of field geologists have been required and the geologic records of the Survey thereby enriched. Incidentally to their regular field work several geologists have visited areas containing developed and undeveloped deposits of granite, slate, Portland cement materials, and gypsum, and the following papers are either direct or incidental results of the work of the past field season. The papers on materials available at Minneapolis, Minn., and at Austin, Tex., excluding the section on cement materials, are examples of the most comprehensive reports made to the Supervising Architect and are given here in substance for the sake of the general information they contain as to typical areas both within and outside of the region of glacial drift.

STRUCTURAL MATERIALS AVAILABLE IN THE VICINITY OF MINNEAPOLIS, MINNESOTA.

By Ernest F. Burchard.

INTRODUCTION.

Within the city limits or a few miles outside of Minneapolis, Minn., are plentiful supplies of limestone for rubble and range rock and for crushed stone; sand and gravel for concrete and mortar; and clay for common building and hollow brick and for fireproofing ware.

The region is within the Wisconsin glacial-drift sheet, and the city is built for the most part on a sand and gravel foundation, but along Mississippi River and at a few places in the northeast section of the city limestone outcrops near enough to the surface to be quarried. As no stone suitable for high-class dimension or cut stone work is available in the city, and as there are areas in Minnesota within 100 miles of Minneapolis which produce granite, sandstone, and magnesian limestone, all of which are used to a considerable extent for handsome buildings in Minneapolis and St. Paul, brief notes will be given on the rocks available at St. Cloud, Ortonville, Kettle River, Kasota, and Mankato.

STONE.

DIMENSION STONE.

GRANITE.

Minnesota is well supplied with granite suitable for building purposes. The two principal granite areas are near St. Cloud and Ortonville, respectively 65 and 179 miles northwest and west of Minneapolis.

St. Cloud granites.—In the vicinity of St. Cloud three kinds of granite are quarried. One is a pinkish-gray medium-grained stone, from which the new federal building at St. Paul has been constructed. The qualities of this stone are therefore well known to the Supervising Architect's office. The Minnesota Geological Survey reports that the gray quartzose syenite from East St. Cloud showed a crushing strength of 26,250 pounds per square inch on "bed" and of 25,750 pounds per square inch on "edge." The ratio of absorption was 1:208. The coarse-grained pinkish-gray granite in the basement of the new capitol building at St. Paul is reported to have been obtained at St. Cloud. There are also fine-grained gray syenites quarried at St. Cloud, and a red syenite. The fine-grained gray rock showed crushing strengths of 28,000 pounds and 26,250 pounds per square inch, respectively on "bed" and on "edge." The red syenite showed practically the same results. The prices of the St. Cloud stone in rough blocks is reported to range from 75 cents to $1.25 per cubic foot.

"Ortonville" granite.—In western Minnesota, near Ortonville, is a dark-red granite that has been used to considerable extent for structural and ornamental purposes in both Minneapolis and St. Paul. There are several columns of polished "Ortonville" granite in the capitol at St. Paul, and the exterior of the handsome city hall and county court-house building at Minneapolis, erected at a cost reported to have been $2,250,000, is faced with dark-red "Ortonville" granite. This stone is rather coarse grained and is capable of being quarried in massive blocks. Of late, however, little has been quarried.

SANDSTONE.

Kettle River.—At the town of Sandstone, on Kettle River and the Great Northern Railway, 87 miles north-northeast of Minneapolis, are large quarries in sandstone, probably of Cambrian age. Two firms operate quarries here, the Kettle River Quarries Company and the Barber Asphalt Paving Company. The rock quarried is a fine-grained light-pink or salmon-colored stone, generally very hard and durable. The sand grains are sharp and many of them sparkle and show recrystallized faces. The relative size of the grains may be indicated by the following sieve tests, which were made on sand derived by crushing the rock until it had been reduced to its individual grains: Remained on 20-mesh, none; on 40-mesh, 30 per cent; passed through 40-mesh, 70 per cent. The cementing material is mainly silica. There are some beds, especially toward the top of the quarry, in which the rock is of a darker shade, varying in color from yellow to brownish red. The face of the Kettle River Company's quarry is about 80 feet high and about 2,200 feet long. Only about 20 feet of stone is selected as the choicest building stone, much of the upper courses being utilized for paving blocks and for heavy masonry. The rock lies in massive beds, 1 to 3 feet thick, and there are three thin zones of shaly sandstone, 16 to 20 feet apart, that divide the quarry face vertically into four divisions. The beds dip 2° to 4° SE. and are jointed in places by well-marked vertical joints that facilitate quarrying but do not prevent blocks 5 to 10 feet long from being easily obtained. This quarry is operated on a large scale and is equipped with all the facilities necessary for a large output of stone, such as electric power, compressed-air drills, 25 large loading derricks, two locomotives, many cars, and several miles of standard track connecting with the Great Northern Railway at Sandstone. There is a large sawmill and cutting shed where dimension stone is cut to order, and the stone, although hard, has been found to be adapted to the highest grade of carved work. For this purpose it rivals granite and is in some respects superior, particularly with reference to its fineness of grains. The rock has a very high crushing strength, tests having been made at the Watertown Arsenal that showed 12,295 and 12,799 pounds per square inch. A chemical analysis made at the same laboratory shows silica, 97.10 per cent; alumina, 2.20 per cent; lime, 0.60 per cent; and magnesia, 0.10 per cent. The stone works very freely, although it shows stratification very faintly, if at all, and contains no fossils. Although there is considerable stripping, such as soil and disintegrated or shaly sandstone, the quarry floor is kept free of rubbish. Nearly all the waste material is utilized in one way or another. Even the sand screened from the crusher is saved. The principal products of the Kettle River Quarries Company are building stone, sawed stone, crushed rock, rubble, paving blocks, curbing, cross walks, bridge stone, coping, and monument bases.

The library building at the University of Illinois was built of this sandstone in 1896. After fourteen years of exposure the stone in this building shows almost the same brightness that it did when first laid in the wall. The stone is chemically so inactive that artificial gases, cements, and other agents that discolor most stones seem to have little or no deleterious effect on it. Other buildings in which the stone has been used are the United Presbyterian Church (interior) at Worcester, Mass.; Spokane Club building, Spokane, Wash.; Des Moines (Iowa) public library; court-houses at Elk Point, S. Dak., Crookston, Grand Rapids, and Benson, Minn., etc. A school building constructed of the stone at Sandstone, Minn., was recently burned out, and the outer walls showed very little effects of the fire. The spalling that occurred was mostly in the window caps and along the coping.

Practically all the virtues of granite appear to be characteristic of this sandstone, with the added advantage of lower cost. Approximate prices quoted are: Rock-faced dimension stone, $1 to $1.25 per cubic foot, f. o. b. the quarries; tool-faced stone, $1.25 to $1.75 per cubic foot; sawed stone, two sides, 50 cents per cubic foot; mill blocks, No. 1, 35 cents per cubic foot; rubble, $1 per cubic yard; and paving blocks, $1.50 per cubic yard.

MAGNESIAN LIMESTONE.

The nearest quarries of a high-grade magnesian limestone that can be tool faced, carved, polished, etc., are at Kasota and Mankato, Minn. Although the stone at both places belongs to the same formation, that at Kasota is more worked for cut stone. The Mankato stone is of a buff color, and that at Kasota is of a light-pink shade, banded faintly in places. The Mankato stone is used largely for massive masonry and as crushed stone, whereas that at Kasota is used for finer building purposes. The stone is a fine-grained, highly magnesian limestone. At Kasota there are quarries operated by the Breen Stone Company and by Babcock & Wilcox. The beds range from a few inches thick at the top (the thinness is due to weathering) to about 4 feet thick below. Massive blocks 12 feet long may be quarried if desired. The stone is quarried to a depth of about 12 feet below the stripping, which amounts to 3 to 5 feet of sand and gravel. In winter the quarries are closed and the beds covered with straw so as to prevent the stone from being disintegrated by frost. The companies mentioned above have cutting shops at Kasota, at which the stone is sawed, tooled, turned, and polished. The supply of stone here is ample and the facilities for its production are larger than the demand.

The United States post-office building at Aberdeen, S. Dak., is faced with Kasota cut stone, and much of the "marble" wainscoting in the Minnesota state capitol building at St. Paul is of polished Kasota stone.

Tests made by Maj. Q. A. Gillmore before 1875 showed this stone to have a crushing strength of 10,700 pounds per square inch on "bed;" specific gravity, 2.63; weight per cubic foot, 164.4 pounds; and ratio of absorption, 1.56.

Present approximate prices at Kasota are: Cut stone, tool faced, $1.25 per cubic foot; polished work—yellow mottled, 75 cents per square foot, and pink mottled, 50 cents per square foot.

RUBBLE AND RANGE ROCK.

The local surface rock at Minneapolis is the "Trenton" limestone. This rock consists of beds of high-calcium, fine-grained, dense light-gray rock, beds of bluish to greenish argillaceous magnesian limestone, and beds that approach shale in texture. The first-mentioned beds are the most desirable for all purposes, but most of the quarries are obliged to move considerable of the inferior stone and more or less of it is worked into the product. In the vicinity of Fifteenth avenue northeast, between Central street and Johnson street, about 1¾ miles northeast of the new post-office site, is an area comprising about 60 acres which supports a large quarrying industry. There are three large quarries operating here, the output of which is mostly crushed stone. These crusher quarries will be described later (p. 287). At the east side of this area is one quarry, that of the A. P. Anderson Stone Company, adjoining the opening of the Minnesota Stone Company, where rubble, heavy blocks, and riprap are quarried. The best material lies at a depth of 18 or 20 feet from the top of the rock and is 8 to 10 feet thick above the base of the quarry. The rock is hard, fine-grained to subcrystalline, wavy bedded, blue-gray limestone. Stone 6 to 15 inches thick and 5 to 6 feet in length are commonly obtained and blocks 3 feet thick are available. This rock is sold mostly for footings in large structures, such as grain elevators. Prices range from $1.70 to $2.50 a perch.

Very high-grade limestone rubble is produced at the quarry of J. A. McLeod, at Second avenue NE. and the Great Northern Railway tracks. About 10 feet of glacial sand and clay overlie the stone, which is fresh, light-gray, fine-grained to subcrystalline, high-calcium limestone. It is sold principally for footings, but the demand is small and much rock that would make good rubble must be run through the crusher.

On the southwest bluff of Mississippi River at two places, near the Milwaukee, St. Paul and Sault Ste. Marie Railway bridge and near Twenty-ninth avenue south, the "Trenton" limestone is quarried for rubble. The quarry near the bridge is operated by Cook Brothers, and quarries in the Twenty-ninth avenue locality are operated by the Riverside Stone Company and by the Twin City Stone Company. The stone is nearly the same at the three river quarries. The upper half is of argillaceous magnesian limestone, which is very soft in places and is termed "soapstone" by the quarrymen. The lower half, generally 12 to 14 feet thick, consists of hard, dense, fine-grained bluish limestone with wavy laminations. This lower rock is the only reliable material in these quarries, and if any rubble is used in the federal building, only hard, blue, high-calcium limestone should be specified. Both rubble and ordinary range stone can be produced from the lower beds in these quarries. Range rock looks well at first, but in a few years the blue color fades to a buff and the laminations become prominent. This is shown in many old-time buildings in Minneapolis. In these river quarries there is only two or three years' supply of stone, because the park board has acquired the river front and has set a limit beyond which the stone may not be quarried into the bluff.

Present prices on stone, delivered, per perch, are for rubble $1.15 and for range $2.85. Sills and dimension stone are sold at about 25 cents per linear foot, 6 inches thick, loaded at the quarry.

MATERIALS FOR CONCRETE.

SAND AND GRAVEL.

The sand and gravel situation at Minneapolis is unique. The city is built largely on deposits of sand and gravel of glacial origin, and for the most part, heretofore, the sand and gravel needed for building purposes have been taken from the excavations for the buildings themselves. The surplus sand and gravel from excavations for small buildings and residences has been hauled away and used in the construction of the large business blocks in the downtown district, which may have required more sand and gravel than could be obtained from their own excavations. Of late the sand business has expanded a little, and in the southern portion of the city, between Mississippi River and the lakes, a number of pits have been opened in the low hills that are characteristic of the topography. When the hills have been leveled the lots are platted and sold for residence purposes. The business of preparing sand and gravel on a large scale has only just started in Minneapolis, but there is great need for a plentiful supply of uniformly clean material. One small plant, where sand is dry screened, has been erected near Lake of the Isles, and a plant to wash and screen sand, projected near Cedar Lake, may be in operation by the summer of 1910.

Efforts were made to ascertain the possibilities of securing supplies of sand and gravel from the excavation that will be necessary if the post-office building is erected on the block now owned by the Government, bounded by Washington avenue, Second street, Second avenue south, and Third avenue south. It was learned that the south half of the block occupies filled ground and that no sand nor gravel may be expected there. Test pits made under the supervision of the custodian of the site, as well as sewer records, show this to be true. Sewer records indicate that there may be 10 or 12 feet of sand and ferruginous gravel in the northern third of the block, and the same opinion is expressed by certain contractors who have erected structures in the vicinity.

Sand from several building excavations in the business part of Minneapolis, near the river, was examined. Nowhere was it of uniform quality. Some silt was invariably present, and the sand was on the average a little too fine for concrete and was not very sharp. Some gravel can be screened out of the sand, but generally it has to be supplemented by crushed stone, as the quantity is insufficient.

Specifications for all sand and gravel used in Minneapolis work should call for screened material, because the run of bank material is not uniformly reliable.

There are several pits in the southern part of the city, southeast of Powder Horn Lake. The pit of E. O. Parker at Thirty-seventh street and Sixteenth avenue south showed several years' supply of material, which consisted mainly of light-gray fine to medium grained sand, with a little small gravel in the upper part and irregular small lenses of torpedo sand and small gravel scattered through the bank. The sand is mainly round and subangular and does not feel sharp. Lime carbonate is present, and some mica and magnetite. There is a little soft, black, carbonaceous matter present in the lenses of torpedo sand, and at various places in the bank small lumps of clay or loam were noted. An average of sieve tests on two samples of sand showed as follows: Passed through quarter-inch mesh, 100 per cent; remained on 20-mesh, 12½ per cent; on 40-mesh, 57 per cent; passed through 40-mesh, 30½ per cent. Soil and loam 1 to 3 feet thick must be stripped from the top, and this work if not carefully done will render the sand very unclean. In the same block with the Parker pit coarser sand had been excavated in building a dwelling, and on the block to the north concrete blocks are being made from the material excavated from a shallow pit showing a larger proportion of small gravel than the Parker pit. It is evident that the material in this vicinity is not uniform in character.

Other outlying pits farther west are worked by Henry Prinz, who hauls 100 to 120 yards of sand a day, of about the kind of material described above. There are several other firms engaged in this business, and the average price of the sand and gravel, delivered, is about $1 per cubic yard.

As stated above, the preparation of sand by mechanical methods has just begun in Minneapolis. One firm, the Nelson Brothers Paving and Construction Company, operates a pit and plant between Cedar Lake and Lake of the Isles, at Dean boulevard and the Chicago, Milwaukee and St. Paul Railway tracks. This firm has 6 acres of sand and gravel, 10 to 20 feet deep. Two pits are open, showing 10 feet or more of gravel, not yet to bottom. An overburden of black soil and brown gravelly clay must be removed to a depth of 2 to 4 feet. The bank shows irregular layers of mixed sand and gravel and layers of sand with little gravel. The sand is grayish to grayish brown and ranges from medium grained to coarse. It is subangular, round, or angular and feels sharp. The sand is clean unless clay gets in from above and ordinarily does not give any stain. Lime is present, and a little magnetite. The sand is mostly quartz but contains some feldspar and other crystalline materials derived from the disintegration of granite and gneiss pebbles and bowlders. Sieve tests on sand passing quarter-inch sieve showed: On 20-mesh, 47 per cent; on 40-mesh, 40 per cent; through 40-mesh, 13 per cent. The proportion of sand in the bank passing quarter-inch screen is about 60 per cent.

The gravel in this bank ranges from small pebbles to cobbles 3 or 4 inches in diameter and small bowlders. The coarser material occurs in the upper parts. The gravel is composed largely of dolomite, with pebbles of granite, gabbro, gneiss, chert, and sandstone and a few of clay shale. Some pebbles of rotten argillaceous limestone and dolomite, as well as decomposed crystalline rock, were noted. The pit is worked on a comparatively large scale, the plant having a capacity of 100 yards a day. The material is screened dry through a rotary double-jacket screen having 1¼-inch, ½-inch, and ¼-inch apertures. The product is loaded on cars and delivered to yards in the center of the city, whence it is distributed by wagons. Some of the product is used at the plant in the manufacture of concrete blocks and sidewalk slabs.

General prices are, for bank-run material, delivered on the job, $1 a cubic yard, and for screened material, $1.10 a yard.

CRUSHED LIMESTONE.

The "Trenton" limestone that is quarried in the vicinity of Fifteenth avenue NE., between Central street and Johnson street, is converted into crushed stone by three large crushers. These crushers are operated by the Blue Limestone Company, the Minneapolis Crushed Stone Company, and the Minnesota Crushed Stone Company, and their entire output, about 200,000 cubic yards annually, is handled by the Mineral Supply Company, a selling company. The beds quarried by these firms dip gently to the southeast, so that the beds which are quarried by the Blue Limestone Company at the west lie in the bottom of the quarry of the Minnesota Crushed Stone Company at the east. The beds quarried by the Blue Limestone Company consist of a bluish-gray, fine-grained, thin, wavy-bedded limestone, much broken by joints and containing some argillaceous shaly material on the bedding planes. The rock weathers to a grayish-buff color. The material is so badly broken by nature that it is adapted only to being crushed. When it is crushed and well screened a product of excellent grade is obtained. The crushed stone from these wavy limestone beds runs high in calcium carbonate and is the strongest and most durable of the rock exploited here. These beds are about 15 feet thick, and because they dip to the southeast they occupy only the lower two-thirds of the face in the Minneapolis Crushed Stone Company's quarry. They are overlain by a thicker-bedded, argillaceous magnesian limestone. The rock in these upper beds is apparently good and sound, but on account of its composition it does not prove as strong or as durable as the blue limestone. Still farther east, at the pit of the Minnesota Crushed Stone Company, the blue-limestone beds are covered by a greater thickness of argillaceous magnesian limestone. This quarry is deeper than the others, about 28 feet deep, so that the blue limestone is obtainable to the extent of perhaps 40 per cent of the product. All these quarries are operated on a large scale and are equipped for handling the stone by the most improved methods for crushing and screening it thoroughly and for shipping by rail. The products are used for concrete and macadam. The stone is screened to the following sizes: Three-eighths to five-eighths inch, five-eighths to 1¼ inches, and 1¼ to 2 inches; and the dust is screened through the ⅜-inch screen. The following prices prevailed in autumn, 1909: Screenings below three-eighths inch, $1.25 per cubic yard; reinforced concrete size, three-eighths inch to 1¼ inches, $1.90; and 2-inch size, $1.75, all delivered in the business district, Minneapolis.

One other quarry, that of J. A. McLeod, at Second avenue and the Great Northern Railway tracks, produces crushed stone. As described above, under the head of rubble (p. 284), the rock quarried here is of the best quality of high-calcium limestone, hard, fine grained, and unweathered.

There is an abundance of well-prepared crushed stone in the Minneapolis district, but the principal caution that deserves emphasis here is that specifications should call for hard, fine-grained, blue, pure limestone, free from argillaceous or magnesian limestone. Physically and chemically, the purer limestone is the superior material.

CRUSHED QUARTZITE.

It was reported to the writer that a very hard quartzite occurring at New Ulm, Minn., is crushed and shipped to Minneapolis under the name of New Ulm "granite." None of this stone was found in the city and prices could not be obtained, but from the nature of the stone it should prove to be a very durable and firm-bonding material.

CEMENT.

No Portland cement is made nearer to Minneapolis than Mason City, Iowa. It is reported that the Universal Portland Cement Company supplies 90 per cent of the trade here, the other brands being principally Chicago A A, Marquette, and Northwestern States. Prices ranged in November, 1909, according to quantity, from $1.10 to $1.50 per barrel, with rebate of 40 cents for sacks. The so-called "bricklayer's" cement, or hydraulic cement, made at Mankato and Austin, Minn., is used here in masonry.

CLAY PRODUCTS.

COMMON BRICK.

Large quantities of common brick are made in Minneapolis and the neighboring towns of Chaska and Coon Creek, Minn., and Menominee, Wis. The brick center of Minneapolis is along Mississippi River, near the north city limits. Eleven brickyards are in operation here. On the west side of the river are the Minneapolis Brick and Tile Company

Krafting & Benson, Frank Johnson, S. G. Johnson, and the city workhouse; on the east side of the river are yards of the Minneapolis Brick and Tile Company, St. Anthony Brick Company, Martin Brick Company, St. Paul Brick Company, Anderson Brick Company, and Northwestern Fireproofing Company. All these firms use a blue calcareous clay deposited in the river valley. All the firms make a stiff-mud brick; most of the brick are side cut, but a few firms make an end-cut brick, and one firm produces a sand-mold, soft-mud brick in connection with its other products. The brick are generally burned with wood or by producer gas. They are of a cream color and the kilns contain 20 to 40 per cent of soft brick. Specifications should therefore call for selected, hard-burned brick, rather than "kiln-run" hard brick. Small lime specks were noted in a few brick, but they are not common, and if the brick are selected lime specks can be avoided. The Minneapolis brick will doubtless fulfill the specifications as a brick for backing and inside work. The brick of the Northwestern Fireproofing Company are reported to have been used in the last addition that was made to the present federal building. The price is now about $9 per thousand for hard-burned brick, delivered.

At Coon Creek, about 15 miles north of Minneapolis, on the Great Northern Railway, the Menomonie Press Brick Company operates a yard having a capacity of about 50,000 brick a day during the working season. Light-red to dark-brown pavers and building brick are made at this plant. The clay used is a slightly calcareous brown glacial clay, comparatively free of pebbles. Where pebbles occur, nearly all are removed by the rolls, but occasionally a small silica pebble or a speck of magnesian-lime carbonate shows in the brick. The brick are of the stiff-mud, side-cut type and are generally burned very hard. Hard brick from Coon Creek can be delivered in Minneapolis at about $10 per thousand. The Menomonie Press Brick Company makes at Menominee, Wis., a soft-mud, sand-mold brick, medium to dark red in color, that can be shipped to Minneapolis, 76 miles, and sold f. o. b. Minneapolis at about $10.40 per thousand.

At Chaska, Minn., 23 miles southwest of Minneapolis, the following firms produce common brick: The Chaska Brick and Tile Company, Riedele & Casper, and the G. H. Klein Brick Company. The combined capacity of these firms is nearly 50,000,000 brick a year. Brick from the Chaska Brick and Tile Company were examined at St. Paul. These brick are cream-colored, soft-mud, sand-mold brick, which show a few lime specks and some spalling and are reported to show efflorescence. All the brick from Chaska are said to be of the same general type. They supply nearly all the demand for common brick in St. Paul and are reported to have been used in the United States post-office building, the Minnesota state capitol, the South

Dakota state capitol, and nearly all the brick buildings in St. Paul for thirty-five years. At present the Chaska brick cost in Minneapolis about $7.20 per thousand.

The Princeton Mercantile Company, Princeton, Minn., manufactures both wire-cut and sand-mold cream-colored common brick. Selected stock sells in Minneapolis at $8.20 per thousand.

FACE BRICK.

Face brick are made by the Twin City Brick Company, at St. Paul, Minn., and by the Menomonie Press Brick Company, Menominee, Wis. The Twin City brick are made from Ordovician ("Trenton") blue clay shale, calcareous in places. The brick are all pressed and, according to the stratum of shale from which they are made or according to the combinations of shale employed, are colored light yellow, gray, greenish, red, or brown. Good hard brick can be obtained here in any desired quantity or shape. The prices range from $14 to $100 per thousand.

The Menominee face brick are pressed brick of various shades of red.

FIREPROOFING BLOCKS.

Hollow blocks and hollow brick, called "fireproofing ware," are made in large quantities at North Minneapolis and at Chaska, Minn. The largest producer of these products is the Northwestern Fireproofing Company, of Minneapolis. The blocks are made from blue river clay, according to the stiff-mud process. The blocks are burned in down-draft kilns by wood fire. Sawdust, to the extent of about 25 per cent by volume, is added to the clay. The sawdust burns out, and leaves the blocks lighter in weight and supposedly tougher. They are of a light cream color, spotted in places by pink, especially where underburned.

Among the products of the Northwestern Fireproofing Company are outside wall tile, arch tile, partition tile, column and girder covering, suspended ceiling tile, book tile for metal roofs, and hollow brick. It is reported by this company that its products have been accepted for use in the federal buildings at the following places: Crookston and Fergus Falls, Minn.; Superior, Wis.; and Grand Forks, N. Dak., as well as in the additions to the present federal building in Minneapolis. Several other firms in North Minneapolis, including the Minneapolis Brick and Tile Company, make similar hollow fireproofing ware. The Chaska Brick Company makes hollow brick and reports that its product was used in the federal building at St. Paul, Minn. Hollow brick are reported to be made also by the Princeton Mercantile Company, at Princeton, Minn.

MATERIALS FOR MORTAR AND PLASTER.

Sand.—Sand for Portland cement mortar and for sanding hard-wall plasters can be screened out of the glacial sand and gravel deposits that yield concrete material. The sand in these deposits is, as a rule, rather fine, so that there is no difficulty in obtaining an abundant supply of suitable material.

Wall plaster.—The nearest gypsum mines are at Fort Dodge, Iowa, where all the standard brands of wall plasters are manufactured. Some raw plaster is reported to be shipped from there to Minneapolis, where it is manufactured into plaster.

SAMPLES.

Samples have been sent for test to the Survey laboratories at Pittsburg as follows: From the Breen Stone Company, Kasota, Minn.: (B 50), six 2-inch cubes of pink magnesian limestone. From pit of Nelson Brothers, Chicago, Milwaukee and St. Paul tracks and Dean boulevard, Minneapolis: (B 51), 50+ pounds of sand, screened through $\frac{1}{4}$-inch mesh screen, and (B 52), 75+ pounds of gravel, passed 2-inch screen. From yards of Minneapolis Brick and Tile Company, 4728 Lyndale avenue, Minneapolis, Minn.: (B 53), three sand-mold soft-mud brick, and (B 54), three wire-cut, stiff-mud brick. From yard of Menomonie Hydraulic Pressed Brick Company, Menominee, Wis.: (B 55), three sand-mold, medium to dark-red veneer brick. From the yard of the same company at Coon Creek, Minn.: (B 56), three wire-cut brick.

In addition to these samples, which have not yet been tested, the Survey has made tests on the crushed blue limestone from the quarry and plant of the Blue Limestone Company, at Fifteenth avenue NE., between Central and Fillmore streets.

STRUCTURAL MATERIALS AVAILABLE IN THE VICINITY OF AUSTIN, TEXAS.

By Ernest F. Burchard.

INTRODUCTION.

Central Texas, within a radius of 75 miles of Austin, is abundantly supplied with almost every variety of mineral structural materials, and this subject has already received attention from a number of investigators. When plans for the state capitol were being formed, a number of building stones were tested by Col. D. W. Flagler at the Rock Island arsenal, October, 1881, and the results were published in the report of the Texas Capitol Building Commission. Mr. E. T. Dumble, formerly state geologist of Texas, was one of the first to call attention to the building stones of Texas, through the medium of the state reports and the technical press.[a] Recently Dr. W. B. Phillips, director of the bureau of economic geology, University of Texas, has begun field and laboratory investigations of the building and ornamental stones of Texas[b] and has arranged in the museum of economic geology at the University of Texas, at Austin, a handsome and instructive exhibit of the most valuable materials.

Mr. Sidney Paige, of the United States Geological Survey, who has been studying the granites in Llano and Burnet counties, Tex., has contributed notes for this report on the granites of that area.

Prof. Alexander Deussen, of the department of economic geology, University of Texas, has cooperated with the writer in the collection of samples of cement materials, whose analyses are given on pages 314–316. The writer desires to acknowledge, with thanks, the assistance of the above-mentioned gentlemen in the preparation of this paper.

The country rock in the immediate vicinity of Austin consists mainly of Cretaceous limestone, shale, and clay. To the east lie younger deposits of sandstone, clay, and lignite of Tertiary age, and to the west and northwest lie older Paleozoic sedimentary rocks, surrounding a central core of ancient crystalline rocks, including large areas of granite. Colorado River cuts through the area from north-

[a] Dumble, E. T., Building stones of Texas: Stone, vol. 5, 1892, pp. 566–570.

[b] Phillips, W. B., Tests on Texas building stones: Min. World, June 24, 1905, pp. 654–657.

west to southeast, and within its immediate valley are Quaternary terrace deposits of clay, and river gravels and sands of more recent deposition. Among the materials of value yielded by the deposits mentioned above are red and gray granite for building and monumental purposes from Burnet and Llano counties; hard and soft white limestone for dimension stone, trimming, and rubble; limestone, clay, and shale for the manufacture of cement; limestone for quick lime, hydrated lime, and crushed stone; sand and gravel for concrete; sand for mortar and plaster. The terrace clays along Colorado River at Austin are used in the manufacture of common and face brick, and from the fire clays in the Tertiary at Elgin, Tex., are produced gray and buff dry-pressed face brick of a handsome type. The limestone and clay are not at present utilized for the manufacture of Portland cement; consequently supplies of this material are shipped in from Dallas and San Antonio, both located on the outcrop of the Austin chalk and adjacent clay, which also underlie Austin.

In view of the possibility of Portland cement being manufactured near Austin, some data are given as to the composition and character of the raw materials in this vicinity essential for Portland cement manufacture. The one important material which does not occur in the immediate vicinity of Austin, but which does occur in great abundance in north Texas, is gypsum, and plasters made from this material are comparatively cheap in the Austin market.

STONE.

LIMESTONE.

GENERAL STATEMENT.

In the immediate vicinity of Austin there are several limestone formations belonging to the Cretaceous system that contain beds suitable for building stone. The lowest formation, stratigraphically, is the Glen Rose limestone. Above this formation, and separated from it by formations of clay and chalky limestone, is another extensive formation known as the Edwards limestone. Overlying the Edwards limestone are the Georgetown and Buda limestones, which are separated from each other by a bed of clay, the Del Rio clay. All these limestones belong to the Lower Cretaceous. In the Upper Cretaceous there is one extensive formation, the Austin chalk, which has yielded stone for building purposes. The character of the most important of the formations just mentioned is described below.[a]

[a] For detailed descriptions, geologic maps, and sections of these formations, the reader is referred to the Austin folio (No. 76) of the Geologic Atlas of the United States, by Robert T. Hill and T. Wayland Vaughan. It may be obtained from the Director, U. S. Geological Survey, Washington, D. C., for 25 cents.

GLEN ROSE LIMESTONE.

The Glen Rose limestone underlies the plateau country northwest of Austin and forms the canyon of Colorado River, beginning about one-half mile above the city dam site and extending up the river for about 20 miles. It is well exposed in the river bluffs of Mount Bonnel and Mount Barker, in the canyons of Dry Creek and Bull Creek, and on the ridge between these creeks. The total thickness of the formation is about 450 feet. It consists principally of alternating hard and soft limestone beds of varying texture. Many of the beds are chalky and some are argillaceous. Occasionally a sandy phase of the rock may be noted, and in few places shaly layers are present. The hard beds are generally compact, but ledges of coarse, honeycombed stone have been noted. The rock is mostly cream-colored, with some white and gray layers and here and there a yellowish layer. The thickness of the individual beds ranges from a few inches to about 10 feet, or more. Many of the beds are fossiliferous and some of the fossils are large and abundant. Some of the beds are slightly oolitic. There appears to be a small proportion of iron oxide and magnesia disseminated throughout the formation, as is indicated by the light-buff or yellow color to which certain of the beds weather on exposure.

About 7 miles by wagon road northwest of the post-office at Austin there are some small quarries in the Glen Rose limestone. Walker's quarry (fig. 23, F) is situated on the hillside, southeast of the creek, and consists of two or three openings in light cream-colored limestone. The highest opening is in a fairly hard, even-grained, fine-textured, slightly oolitic limestone. The rock contains many small fossils, most of which are in a fragmental state. When fresh this stone shows small buff to yellowish specks of iron oxide, which give the stone, in mass, a light-buff tint; but this tint becomes lighter after the stone is thoroughly dry. The rock is horizontally bedded and the best ledge ranges from 10 to 14 inches in thickness. The joints are not numerous in the rock and slabs 3 to 5 feet in length and width may be obtained. Stone from this particular ledge possesses the hardness requisite to receive and hold a tool finish, and it is unfortunate that the ledge is not thicker. In the opinion of local stone masons, however, it is not necessary to lay this stone on its bed, and of course if it can be successfully laid on its edge stones cut from it can be faced in large dimensions. This ledge has been quarried for several hundred feet along the outcrop, where little or no cover had to be removed, and by the removal of a thickness of 2 or 3 feet of thin-bedded stone, débris, etc., an important supply of this stone might be uncovered. Between 60 and 100 feet lower down on the same hillside are softer beds of a finer texture and somewhat lighter color, which have been quarried to a larger extent. The softer stone is more easily worked and may be sawed by hand. It is capable of being tooled in the same manner as the harder stone but probably will not prove as durable. The Walker quarries are not being operated at present, but sufficient work has been done to demonstrate that a large supply of stone is available there.

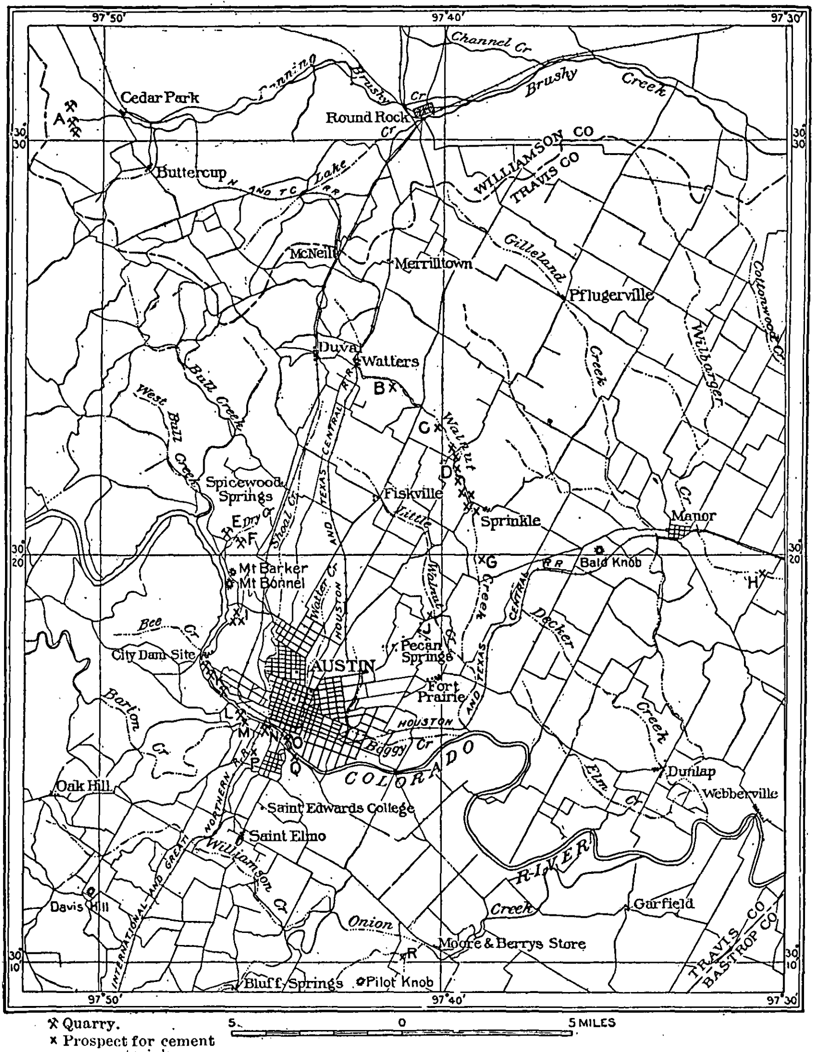


FIGURE 23.—Map of vicinity of Austin, Tex., showing location of stone quarries, gravel pits, brickyards, and prospects sampled for cement materials. From Austin and Georgetown topographic sheets, United States Geological Survey.

Across Dry Creek valley are quarries operated by Patrick Kelly (fig. 23, E), in rocks of the same horizon as those opened at the Walker quarry. The hard ledge at the top barely exceeds a thickness of 10 inches here. The lower ledge of softer rock ranges from 18 to 22 inches in thickness, but it is overlain by 15 inches of cherty limestone, which must be removed in order to get the material suitable for building stone. The principal drawback to working these stones on a large scale has been the distance that they must be hauled to the railroad or to the city. The road passing north of Mount Bonnel is well kept but has a steep grade close to Dry Creek.

The Kelly quarries are operated in a small way, the softer stone being used for building purposes and the harder stone for curbing and monument bases. In small lots the stone costs, at present, about 25 cents per running foot, or 50 cents per cubic foot delivered in Austin.

EDWARDS LIMESTONE.

The Edwards limestone outcrops along Colorado River, a short distance above and below the city dam site, and its outcrop extends and widens to the southwest of Colorado River and to the north of Austin, west of the International and Great Northern Railway. It is composed mostly of limestone, with some marly layers. In general the beds are whitish, but layers of buff, cream, yellow, or dull gray, and even brownish yellow, are present. In composition many of the beds are nearly pure carbonate of lime. The limestones vary greatly in degree of induration, ranging from hard, ringing, durable rock to soft, friable chalk. Some of the beds are coarsely crystalline, with well-preserved fossils, and are capable of being highly polished. Other beds are close grained. Some of the beds are very compact; others are porous and pervious. For building purposes only the compact varieties are of importance, and since there is some variation in the texture of the same bed it is important in prospecting to open up a sufficient space to prove that the bed is homogeneous in texture for some distance. One deleterious feature of the Edwards limestone as regards its suitability for building purposes is the presence of great quantities of chert or flint, which occurs in nodules and sheets of thin, flat lenses. These flints vary in dimension from 2 inches to a foot or more. Fossils are abundant in many of the beds of the Edwards limestone, and these fossils are detrimental in some places where it is desired to secure a stone to be tool faced. If the stone is used as rubble the presence of fossils is not so objectionable. The thickness of the Edwards limestone is probably about 300 feet.

On the northeast side of Colorado River 2 to 3 miles west of the post-office at Austin (fig. 23, K) are several old abandoned quarries in very hard limestone, which is considered to belong in the upper part of the Edwards limestone. One bed in this vicinity is composed of a mass of large fossil shells, which have been almost entirely replaced by calcite. This stone has a white chalky color on fresh fracture, and in places it is tinted cream-yellow and pale pink. It is susceptible of high polish and when polished makes a beautiful stone for interior purposes; on this account it has been called the "Austin marble." It is not at present commercially utilized for decorative purposes but has been largely used as rubble, as may be seen in the facing of the foundation of the present federal building at Austin. Close to these fossiliferous beds are beds of hard light-gray fine-grained limestone, containing only a few fossils. The stone contains numerous crystals of calcite scattered here and there through the mass, and occasionally a slight stain of iron oxide may be noted. The bed most suitable for cut-stone work is about 14 inches thick, and there are a number of other beds from 6 inches to 1 foot in thickness. Stone of this character from the Banker quarry was used in the facing of the present post-office building above the foundations. The rock was tool faced and has withstood the thirty years' exposure to the weather exceedingly well. In January, 1910, the stone appeared to be almost white in color, but it is understood that the building has been cleaned by rubbing two or three times since it was completed, the last cleaning having been done within the past three years. At the Johnson quarry there is a small quantity of stone of this character available which needs no stripping, but in order to obtain a supply of stone sufficient for the new federal building it would probably be necessary to strip one-half acre of stone averaging 6 feet thick, which lies above this homogeneous bed. About a mile west of the Johnson quarry, or three-fourths of a mile below the dam site, is an abandoned quarry in very hard, coarsely crystallized gray limestone, which occurs in massive beds 2 feet or more thick. Little of this stone is available without considerable stripping, but the stone is very durable and of a pleasing color and texture.

At Oak Hill, about 7 miles southwest of Austin (see fig. 23), there occurs a very hard limestone, either in the basal part of the Edwards limestone or in the upper part of the Glen Rose limestone, that is reported to have been used in the foundations of the capitol at Austin.

The most extensive working quarries of building limestone in the vicinity of Austin are at Cedar Park, on the Houston and Texas Central Railroad, about 27 miles northwest of Austin. This rock, which is here provisionally referred to the Edwards limestone, outcrops, or lies below only a few inches of soil, over a large area of the divide between Colorado and San Gabriel rivers, west of the Houston and Texas Central Railroad. It is quarried at three places, west and northwest of the station of Cedar Park (fig. 23, A), and is hauled to the railroad at Cedar Park and to Leander. The rock that is quarried consists almost entirely of calcium carbonate and is soft enough when freshly quarried to be cut with a handsaw. When fresh and containing quarry moisture, the rock is decidedly cream-colored. When removed from the quarry it soon dries to light gray or nearly to white. After weathering it becomes of a light-cream to light-buff color. The rock is compact, fine grained to subcrystalline, and in places slightly oolitic. The beds are massive and show no stratification within 6 or 7 feet of the surface, the maximum depth to which the rock has been opened by working. The rock that is quarried is slightly fossiliferous, and it is reported that below the portion that is quarried fossils are so numerous as to render the stone less desirable. The rock has a metallic bell-like ring in large blocks, especially when dry. It is reported to weigh 150 pounds per cubic foot and to withstand a crushing strength of about 2,960 pounds per square inch. Relatively, therefore, this rock is not very hard or strong, but it appears suitable for building purposes in the dry climate of central and southwest Texas, where it has been used probably more than any other of the local stones, both for facing and for sills, caps, water tables, columns, and other exterior trimmings. The two quarries nearest to Cedar Park are operated by Cluck & Richards and E. Cluck & Bro. The stone is stripped by scrapers and by hand and is quarried by channeling to depths of 5 to 7 feet, boring under the blocks by hand augers, and then wedging them up. The quarries of the above-mentioned firms consist of irregularly shaped pits about 300 feet long. The rock is handled by derricks and hauled by wagon to the railroad in mill blocks. The only limitation to the size of blocks obtainable lies in the facilities for lifting and transporting the stone. The stone is so easily cut and dressed on the job that the quarrymen do not attempt to produce dimension stone. The present prices on the stone are, in mill blocks, 20 to 25 cents per cubic foot, f. o. b. Cedar Park. The combined output of these quarries is more than 50,000 cubic feet of stone annually, and the supply of stone that is available under present conditions is very great, because the above companies control 400 acres of stone land. It is reported that the stone at Cedar Park has been used in federal buildings at Gainesville and Laredo, Tex.

AUSTIN CHALK.

The Austin chalk occupies a northeast-southwest belt, from 2 to 5 miles wide, within which is the city of Austin. This formation has been traced from a point north of Dallas to one southwest of San Antonio and is very similar in character throughout its extent. The rock is a white chalky limestone of fine to coarse texture and occurs in beds of varying thickness, separated in places by friable beds of marl. When fresh and impregnated with ground water the chalk has a bluish tint, but it usually bleaches white when dry and in places shows slight blotches of yellow from the oxidation of specks of iron pyrite. Fossils are abundant in places in the Austin chalk and range from the shells of Foraminifera and other minute organisms to large *Inoceramus*, oyster shells, and ammonites. The Austin chalk may be some 500 feet thick, and for the most part its beds are very poorly indurated. In all localities noted the hardest beds were softer than the stone at Cedar Park described above. One sample of stone, which is very fine grained, homogeneous, of a light cream color, and susceptible of a smooth rubbed finish, was produced from the property of Fisher & Bro., about 7 miles southwest of Austin, about one-fourth mile from the International and Great Northern Railroad. It is reported that this stone can be delivered in Austin for about 30 cents a cubic foot.

GRANITE.

INTRODUCTORY STATEMENT.

Within the past two years the United States Geological Survey has been making a geologic map of the Burnet and Llano quadrangles, northwest of Austin. Mr. Sidney Paige, one of the geologists engaged on this work, has mapped the granites in the field and has made detailed studies of them in thin sections under the microscope. The following notes on granite are contributed by Mr. Paige.

GENERAL OCCURRENCE.

Granite occurs in great abundance in the pre-Cambrian complex of Llano and Burnet counties, Tex. Many large areas exist where pure, clean stone can be found. Many areas exist also where the granites are mixed with fragments of the schists which they have intruded. The opening of quarries in areas characterized by this latter condition is always a more or less hazardous undertaking, for though an area may be selected which seems quite sufficient to form a workable quarry floor, no assurance can be had that the rock will continue clean in depth. A number of such quarries have been opened in Llano County, and the experience of quarrymen has shown that much care must be exercised to avoid such mixed zones. The desire to obtain a stone easily worked has been one of the factors leading to the selection of such localities, for clean rock in areas where it was very little altered has been reported to be too hard to be desirable by the monument workers. Why the stone should be softer in these mixed areas is not known.

Though there are present in this region many varieties of stone, a rough classification may be made into (1) a coarse-grained pink variety, (2) a fine to medium grained gray variety, and (3) a fine to medium grained pink variety.

The first has been most extensively quarried at Granite Mountain, Burnet County. In Llano County Teich's quarry No. 2 has produced stone of this character.

Of the fine to medium grained varieties the gray is far more abundant. In many places granite that is pink on the surface will prove gray in depth. There do exist, however, in this region pink granites of fine to medium grain.

The coarse-grained granite of southwestern Llano County will probably some day be utilized. There is an almost unlimited quantity of this stone.

Facilities for shipment undoubtedly vitally affect the Llano County granite industry. With increasing growth of the large cities in the South and with additional railroads there should be established a more profitable and extensive industry than exists at present. Though now the larger part of the rock is used for monumental purposes, there is much granite eminently suited for large structures if means of shipment were better and a more active market available. Until such a condition exists it is doubtful if any considerable growth of the industry will take place. The construction of the Galveston jetty has provided one of the largest markets for rough and crushed stone.

GRANITE MOUNTAIN QUARRY.

The Granite Mountain quarry is located on the Houston and Texas Central Railroad at Granite Mountain, Burnet County, near the town of Marble Falls. The owners since 1893 are Darragh & Catterson. Before that date the property was owned by Lacey, Westfall & Norton.

The quarry is opened in the side of a broad, low, bare granite hill. No stripping is necessary. Sufficient granite is exposed above the present railroad grade to furnish material for a great many years.

The rock is a coarse-grained pink granite, consisting of quartz, microcline (dominant), albite oligoclase and some orthoclase feldspars, and biotite mica. Though portions of the mass are intruded by pegmatite, an enormous quantity of fine material is at hand. A well-defined rift aids quarrying. Sheets of any desirable thickness can be lifted, and handling sets the only limit to the size of blocks that may be obtained. The greater part of the rock quarried has been shipped in 5 to 10 ton blocks and as crushed stone to the Galveston sea wall. This work was begun in 1891 and continued to 1898. Little work was done from 1898 to 1902. From 1902 to the present time about 1,000,000 tons of rock was shipped. Before that, however, 2,000,000 tons was shipped, and in addition 120,000 yards of crushed rock has been used on the same work. Probably 2,000,000 tons was used as cap rock.

The capitol building at Austin, begun in 1884 and finished in 1899, and court-houses in Galveston, Houston, and other localities are built of this granite. Nevertheless, but a small part of the output has been dimension stone. This class of work will probably grow in importance.

The quarry is equipped with 20-ton rigging. There are five derricks, a 1,500-foot cableway, and a tram. The rock is generally swung direct to the cars. A No. 7½ Gates crusher is also installed. Engineers are paid $2.50 to $3.50; derrickmen, $2.75 to $3; foremen, $4; common laborers, $1.50 to $1.75.

Freight rates per ton on rough granite.

Granite Mountain to Galveston	$1.25
Granite Mountain to Houston	1.15
Granite Mountain to Aransas Pass	1.40
Granite Mountain to Sabine Pass	1.35
Granite Mountain to San Antonio	1.00
Granite Mountain to Fort Worth and Dallas	1.30

TEICH QUARRY NO. 2.

This quarry is a short distance west of Kingsland, Llano County, and is connected by a spur with the Houston and Texas Central Railroad. It is owned by Frank Teich, of Llano, and was opened in 1908. The rock is a coarse-grained pink granite and takes a fine polish. The Memorial Church of Orange, Tex., is built of this rock. About 50,000 cubic feet have been quarried, valued at 50 cents a cubic foot. The quarry was not being worked when it was visited.

Mr. Teich operated a small quarry on the Parkinson tract 6 miles south of Llano during the summer of 1909. About 6,000 cubic feet was extracted and manufactured into monuments at Teich's polishing works near Llano. This quarry was abandoned the past summer. A new quarry, Teich No. 3, is being opened about 4 miles south of Llano.

GOOTCH & WELLS QUARRY.

Gootch & Wells are operating a quarry on the Parkinson tract about 6 miles south of Llano, Llano County. The quarry presents a very rough and irregular appearance. The pit is from 25 to 50 feet deep and about 150 feet long in an east-west direction. It is about 100 feet wide at the east end, but narrows to 15 or 20 feet at the west end. The rock lies in somewhat irregular sheets broken by vertical joints. N. 50° E. is the easiest break.

The following section will give an idea of the sheeting:

Section showing sheeting in Gootch & Wells quarry, Llano County, Tex.

	Feet.
Top ledge, not used (low dip northwest)	5–10
Rotten granite	1– 2
Thick ledge	12±
Rotten seam	½
Ledge	8
Ledge	4

The thickness of the sheets varies considerably and the presence in parts of the quarry of pegmatite and schist inclusions spoils much rock. The stone is a beautiful gray granite, somewhat resembling the stone of Barre, Vt. It consists of quartz and microcline feldspar, with a little albite oligoclase and orthoclase feldspar. Biotite in small flakes is the dark mineral. The quarry is equipped with four derricks, a gasoline engine, and five air drills. Plug and feathers are largely used for breaking on the finish work. If pushed, the quarry could produce 250 cubic feet per day.

The granite is hauled to the Houston and Texas Central Railroad at Llano by wagons at a cost of 15 cents a cubic foot. Freight on rough stock varies from 50 cents to $2.50 a ton in the State. From Llano to Houston the rate is $1.45. The entire product of the quarries is used for monumental work. The actual cost of quarrying is about 40 cents a cubic foot, varying with the nature of the seams in the quarry. The rough stone is sold from the quarry. Dressing costs from $1 to $25 a cubic foot, depending on the designs. The best quality of stock sells for $1.50 a cubic foot, this grade being used for the best polished work. The cheapest stock, used for hammered work, sells for 90 cents a cubic foot.

The quarry produced during 1908 about 18,000 cubic feet and will produce during 1909 about 22,000 feet. The entire Parkinson tract produced during 1908 (including quarries operated by George Patterson, T. A. Blodgett, Mr. Seiter, and Frank Teich) about 33,000 cubic feet.

NORTON QUARRY.

The Norton quarry, owned by Mrs. Norton, of Llano, is about 11½ miles southwest of Llano and about 3½ miles a little east of south of Sixmile post-office. The quarry pit is nearly rectangular, and measures 95 feet long in a north and south direction. It is about 55 feet wide and 12 to 15 feet deep. Natural walls caused by small north and south seams make the west and east sides. The north end, trending N. 60° E., is a very straight break. The rock breaks easiest the "capping way," while north-south and east-west breaks are about the same in this respect. The stone is a bluish-gray fine-grained granite composed of quartz and microcline feldspar essentially, with a little albite oligoclase and orthoclase. The dark mineral is biotite mica in fine flakes. A little chlorite is present. Pyrite was noted, occupying almost invisible seams. It is not abundant, however, though some fine blocks are spoiled by its presence. Schist fragments also spoil some of the other rock. The plant consists of two derricks and a horse winze.

E. L. STEWART QUARRY.

Mr. E. L. Stewart, in August, 1908, opened a new quarry near the old Stewart quarry, about 10½ miles southwest of Llano and about 2½ miles a little west of south of Sixmile post-office.

The rock is a fine-grained gray granite. Pyrite is very abundant in parts of the old Stewart quarry near by and may also interfere with the new opening. Schistose material is included in much of the granite of the vicinity, and this fact, combined with the presence of pyrite and the long haul to the railroad, will probably prevent extensive developments. Two carloads have been shipped to San Antonio and Paris markets, principally for monumental purposes. The rock is hauled for 25 cents a cubic foot loaded at the quarry and unloaded at Llano. Quarrymen receive from $2 to $2.50 a day.

BRADSHAW QUARRY.

Mr. Bradshaw has opened a small quarry one-fourth mile west of the Gootch & Wells quarry. Only the top rock has been removed over a small area.

H. P. BAILEY QUARRY.

Mr. H. P. Bailey is also opening up a quarry three-fourths of a mile north of Bradshaw's. Only a few cubic feet of rock has been quarried.

OTHER LOCALITIES.

Mr. George Patterson is operating a quarry on the Parkinson tract south of Llano, but no notes are at hand covering the work.

A number of quarries have been worked in the past, but for the present at least are abandoned. Such are the Town Park quarry north of Llano, where pyrite marred a very beautiful coarse-grained gray granite porphyry; the Kansas City quarry, 2 miles west of Llano on the Mason road; and the quarry 7 miles northwest of Burnet, where a very dark gray, slightly gneissoid granite has been quarried.

RESULTS OF TESTS.

The following table, showing the results of tests of compressive strength and other physical properties, permits a direct comparison of the various Texas building stones.

Results of tests of Texas building stones.[a]

No.	Material.	Location.	Dimensions.			Compressive strength.			Percentage of absorption.	Specific gravity.	Weight per cubic foot.
			Height.	Cross section.	Area of cross section.	Pressure at which it cracked and spalled.	Pressure at which it crushed.	Crushing strength per square inch.			
			Inches.	*Inches.*	*Sq. in.*	*Pounds.*	*Pounds.*	*Pounds.*			*Pounds.*
1	Limestone	Austin (court-house stone)	4	2. 25 by 2. 25	5. 027	17, 200	17, 200	3, 422	0. 068	2. 1616	134. 76
2	Do	Duval, Gault quarry	4	2. 20 by 2. 25	4. 95	28, 300	31, 200	6, 303	. 031	2. 3915	149. 09
3	Do	8 miles from Austin, Hancock quarry	4	2. 37 by 2. 37	5. 617	12, 000	12, 800	2, 279	. 058	2. 1794	135. 86
4	Limestone (fossil)	Austin, Loomis & Christian quarry	4	2. 28 by 2. 25	5. 13	22, 300	42, 100	8, 207	. 011	2. 5992	162. 03
5	Limestone	Burnet County, Honey Creek	4	2 by 2	4	35, 000	59, 800	14, 950	. 0004	2. 7057	168. 67
6	Do	12 miles south of Austin, Slaughter Creek	4	2 by 2	4	....	80, 115	20, 029	. 0623	2. 25	....
7	Do	.....do	4	2 by 2	4	....	58, 180	14, 545	. 0597	2. 278	....
8	Do	.....do	4	2 by 2	4	....	79, 000	19, 750	. 0655	2. 251	....
9	Do	.....do	4	2 by 2	4	....	81, 280	20, 320	. 0092	2. 588	....
10	Do	13 miles south of Austin, Bear Creek	4	2 by 2	4	....	29, 365	7, 341	. 0899	2. 119	....
11	Do	.....do	4	2 by 2	4	....	49, 020	12, 255	. 0845	2. 153	....
12	Do	.....do	4	2 by 2	4	....	40, 040	10, 010	. 0554	2. 265	....
13	Do	.....do	4	2 by 2	4	....	29, 220	7, 305	. 0589	2. 248	....
14	Do	Cedar Park	1	1 by 1	1	2, 300	2, 300	2, 300	. 1021	3. 47	157. 87
15	Do	Round Rock	1	1 by 1	1	1, 495	1, 495	1, 495	. 1205	3. 26	144. 77
16	Do	McLennan County	1	1 by 1	1	3, 180	3, 180	3, 180	. 0573	2. 97	158. 49
17	Do	Lueders, Jones County	1	1 by 1	1	2, 487	2, 487	2, 487	. 0474	2. 91	160. 37
18	Marble	Burnet County, Fort Croghan quarry	4	2. 27 by 2. 24	5. 0848	69, 290	70, 080	13, 782	. 0039	2. 679	166. 99
19	Marble (pink)	San Saba County	1	1 by 1	1	5, 100	10, 330	10, 330	. 0062	2. 81	166. 7
20	Marble (black)	Brewster County, Jordan quarry	1	1 by 1	1	....	10, 420	10, 420	. 0016	2. 74	170. 35
21	Marble (white)	.....do	1	1 by 1	1	....	3, 784	3, 784	. 0021	2. 10	130. 41
22	Sandstone	Fairland, Burnet County	1	1 by 1	1	2, 800	4, 450	4, 450	. 0601	2. 91	154. 75
23	Sandstone (gray)	Moulton, Lavaca County	1	1 by 1	1	2, 100	2, 400	2, 400	. 0941	2. 81	149. 76
24	Sandstone (red)	Ward County	1	1 by 1	1	1, 900	2, 000	2, 000	. 0738	3. 04	156
25	Granite (red)	Burnet County	4	2 by 2. 11	4. 22	49, 900	50, 180	11, 891	. 0009	2. 625	163. 64
26	Do	Llano County, Teich quarry	1	1 by 1	1	9, 600	11, 990	11, 990	. 0028	2. 64	163. 49
27	Granite (gray)	.....do	1	1 by 1	1	10, 900	11, 950	11, 950	. 0028	2. 69	165. 98
28	Do	Llano County, Bradshaw quarry	1	1 by 1	1	7, 970	10, 060	10, 060	. 0021	2. 70	167. 23
29	Granite (light-gray)	Burnet County, Ueberali quarry	1	1 by 1	1	8, 310	9, 340	9, 340	. 0021	2. 76	170. 97
30	Granite (dark-gray)	.....do	1	1 by 1	1	10, 650	10, 880	10, 880	. 0021	2. 95	182. 83
31	Granite ("opal")	Llano County	1	1 by 1	1	11, 800	15, 300	15, 300	. 0036	2. 67	164. 73
32	Granite	Presidio County	1	1 by 1	1	7, 220	15, 970	15, 970	. 0073	2. 67	163. 49
33	Serpentine	Gillespie County, 35 miles south of Llano	1	1 by 1	1	8, 400	8, 950	8, 950	. 0079	2. 61	159. 74

[a] Nos. 1 to 13, 18, and 25 were tested by Col. D. W. Flagler at Rock Island Arsenal, October, 1881, and the data published in the report of the Texas Capitol Building Commissioners, 1883. Nos. 14 to 17, 19 to 24, and 26 to 33 were tested at the engineering department, University of Texas, and the data published by Dr. W. B. Phillips, of the University of Texas, in the Mining World, June 24, 1905.

MATERIALS FOR CONCRETE.

SAND.

The supplies of sand used in Austin and vicinity are derived from the bars along Colorado River, above and below the new concrete bridge at the foot of Congress avenue. At low water there is a bar at least one-half mile long, 600 feet wide, and 3 to 5 feet deep above low-water level (fig. 23, O). The material in this bar consists of fine sand to coarse gravel and small bowlders. In places there are layers of silt and quicksand, but pockets of materials that have been washed thoroughly clean by the water are extensive, and sand of almost any degree of coarseness may be obtained. The sand is light pink and consists chiefly of quartz and pink feldspar grains, together with a small proportion of limestone, magnetite, and traces of white mica flakes. The sand grains are subangular, round, or angular and feel sharp and gritty. The sand usually leaves little or no clay stain on the hand. When it is treated with hydrochloric acid a brisk effervescence is noted, due to the presence of grains of limestone and fine shell fragments. A sieve test on a sample averaged from sands from two points on the bar showed results as follows: Passed through $\frac{1}{4}$-inch mesh, 100 per cent; remained on 20-mesh, 20 per cent; on 40-mesh, 55 per cent; passed through 40-mesh, 25 per cent.

The sand thus appears to be well graded and low in voids. The supply available at low water is inexhaustible at the present rate of excavation. It is hauled by teams from the river to any point in Austin and is shipped by carload lots to many points within a radius of 100 miles of the city. It is used for stone and brick mortar, concrete, and plaster. In small quantities it will cost about 75 cents a square yard delivered in Austin. The cost for large quantities delivered at the post-office site, which is not a long haul, should be considerably less.

GRAVEL.

Gravel may be obtained in abundance from the bar described above in connection with sand. The gravel occurs in places clean enough to be used without screening, but is mostly mixed with sand. The gravel consists mainly of rounded pebbles of limestone, quartz, chert, jasper, and of granitic rocks from the crystalline area in Llano and Burnet counties, from which the material has been transported by the river. The gravel of Colorado River is used together with sand very generally for concrete walks in Austin and to some extent for building purposes. A noteworthy example of the use of this gravel and sand in concrete is the new concrete bridge across Colorado River at the foot of Congress avenue. This bridge has just been completed of poured concrete. The sand and gravel were obtained from the bar just above the bridge. The sand was screened out of the gravel, washed down a chute, then remixed with the gravel in definite proportions to form the aggregate.

CRUSHED STONE.

Crushed limestone is delivered to the Austin market from the quarries of the Dittlinger Lime Company, near New Braunfels, about 50 miles south-southwest of Austin on the International and Great Northern Railroad. The crushed stone produced at this place is cream-colored to light yellowish and appears to be well graded and fairly well screened but contains some dust. One good feature of the stone is the approximately cubical shape taken by the crushed fragments. The Dittlinger Company operates a No. 5 Simons crusher, with a rotary screen, making four separations, as follows: Screenings below $\frac{5}{16}$ inch; stone between $\frac{5}{16}$ inch and 1 inch, between 1 inch and $1\frac{5}{8}$ inches, and between $1\frac{5}{8}$ inches and $2\frac{1}{2}$ inches.

The capacity of the plant is about 150 cubic yards a day, and the cost of the material, f. o. b. Austin, ranges from $1.30 to $1.55 a short ton.

CEMENT.

No Portland cement is at present manufactured at Austin, although, as will be shown below, there are raw materials here in abundance for such manufacture. The principal supplies of cement are shipped from Dallas, and the present prices are quoted at about $2 a barrel, delivered, not including the price of sacks.

BRICK.

GENERAL STATEMENT.

Two firms are manufacturing brick at Austin. Both obtain their clay from the low terrace on the south bank of Colorado River. (See fig. 23, N and L.) The Butler Brick Works are located on the south bank of the river, just west of the International and Great Northern Railroad tracks. The Austin Brick Company's brickyard is on the north bank of the river, about three-fourths of a mile west of the International and Great Northern Railroad bridge, and the supplies of clay are conveyed across the river from the pit to the brickyard on an aerial cableway. Both these yards manufacture a soft-mud, sand-mold common brick and a dry-pressed brick which is designed for use as a moderate-priced face brick.

COMMON BRICK.

The common brick made by both firms are cream-colored, fairly uniform brick, some of them showing a few lime specks and spalls. The brick are burned in permanent-wall, side-fired, updraft kilns, using Rockdale (Tex.) lignite as fuel. The brick show a good sharp break and are not very hard. They are easily overburned, as they tend to fuse at a comparatively low temperature. When underburned the brick are mottled pink in color, so that soft brick are easily detected. The capacity of each plant is about 30,000 sand-mold brick per day, and the stock ranges from 100,000 to 1,000,000 brick, which are stored in the kiln sheds. Present prices on the common brick, delivered in Austin, range from $7.50 to $8 per thousand.

FACE BRICK.

The face brick made by each firm are of a dry-pressed, bright cream-yellow variety, show good sharp edges and a sharp break, but are not very hard. The porosity of these brick appears to be relatively high, and the fusing point at which the clay was burned is relatively low, owing to the high percentage of calcium carbonate in the clay. (See analyses Cy 30 and Cy 31, page 315.) These dry-pressed brick are burned in downdraft kilns with Rockdale lignite as fuel. From 20,000 to 30,000 brick a day are made by each plant. Stocks of 100,000 to 500,000 brick are carried in the kilns. The cost of these brick, delivered in Austin, at present is $13 to $15 a thousand.

Tests on soft-mud brick from Butler's brickyard, made at the engineering department of the University of Texas, showed crushing strengths per square inch ranging from 2,855 to 3,434 pounds, and on dry-pressed brick they ranged from 3,797 to 4,801 pounds. Absorption of the soft-mud brick ranged from 18.1 to 20.74 per cent and of the dry-pressed brick from 19.5 to 21.4 per cent. The crushing tests were made on one-half bricks.

The Butler Company operates at Elgin, Tex., 27 miles east-southeast of Austin, on the Houston and Texas Central Railroad, a brickyard known as the Elgin-Butler Brick and Tile Company's, at which face brick and fire brick are made. The face brick range from light gray to buff in color and are embellished with manganese specks in varying quantities. The brick are made by the dry-press process from fire clay, which is first crushed in a dry pan and screened. Oil is used as fuel, and the kilns in which the brick are burned are of the downdraft pattern. These brick are uniform in size and are shaded in five or six different colors. About 40,000 brick a day are reported to be made at this plant, and a stock of some few hundred thousand brick is carried under sheds. The present price of these brick is about $24 per thousand, f. o. b. Austin. Shade No. 415, a light-gray brick, finely specked with manganese, is said to have been used in the federal building at Houston, Tex.

Tests made by A. C. Scott at the University of Texas in 1909 on one-half bricks from the Elgin-Butler Brick Company showed results as follows:

Tests on face brick from Elgin-Butler Brick Company, Elgin, Tex.

Brick No. 425, surface, 17.27 square inches:
- Failure started at 78,000 pounds, or 4,516 pounds per square inch.
- Failure was total at 90,600 pounds, or 5,246 pounds per square inch.

Brick No. 450, surface, 17.27 square inches:
- Failure started at 77,600 pounds, or 4,493 pounds per square inch.
- Failure was total at 100,000 pounds, or 5,790 pounds per square inch.

MATERIALS FOR MORTAR AND PLASTER.

Sand.—The sand of Colorado River described above is used for all classes of mortar and plastering work. It is generally necessary to screen the sand in order to secure a sufficiently fine-grained material for these purposes.

Lime.—Lime is manufactured at three places in the vicinity of Austin, namely, at McNeil (fig. 23), by the Austin White Lime Company; at Round Rock (fig. 23), by the Round Rock White Lime Company; and at New Braunfels, by the Dittlinger Lime Company. All these companies manufacture from high-calcium Cretaceous limestone, and both hydrated lime and quicklime are produced by the three firms. These products cost in Austin about 80 cents per 200-pound barrel.

Plaster.—Gypsum wall plasters manufactured in northern Texas are used at Austin. The Acme Cement Plaster Company puts the following products on the market: Cement plaster (brown coat), at $9 a ton, delivered; white plaster (stucco or plaster of Paris), at $10.50 a ton; Keene's cement, at $19.50 a ton.

The Agatite brands of plaster, manufactured by the American Cement Plaster Company, consist of the same varieties (except Keene's cement, which the company does not manufacture) and retail at the same prices.

SAMPLES.

Samples as follows have been sent for test to the Survey laboratory at Pittsburg, Pa.: B 79, sand from Colorado River, below wagon bridge, Austin, Tex.; B 80, sand and fine gravel; B 81, sand and coarser gravel; B 82, gravel. All these samples are from the same bar in Colorado River and consist of about 50 pounds each.

NOTES ON PORTLAND CEMENT MAKING MATERIALS.

GENERAL STATEMENT.

The results of a number of chemical analyses of limestone, clay, etc., from the vicinity of Austin, Tex., are given below. They were made at the laboratories of the United States Geological Survey in St. Louis in 1908, on representative samples of material ranging generally from 20 to 50 pounds in weight, and are part of a series of tests that were planned for the promising deposits of undeveloped cement-making materials of the United States. Along with these analyses it was planned to make kiln tests on the raw materials and certain experiments with various fuels, including lignite and producer gas, to grind the clinker, and to make the usual physical tests on the resulting cement, but lack of the necessary funds prevented a continuation of this work in 1909.

CHARACTER OF THE ROCKS.

Beginning with the lowest formation the rocks here considered of possible value as cement materials are as follows: The Georgetown limestone and Del Rio clay, both of the Lower Cretaceous, and the Eagle Ford clay, Austin chalk, Taylor marl, and Webberville formation of the Upper Cretaceous. In the valley of Colorado River are terrace silts of Quaternary age. These silts overlie the Cretaceous unconformably. The formations strike northeast-southwest and dip at low angles to the southeast. The oldest rocks outcrop just west of Austin, the later ones overlapping from the east.

The Georgetown limestone consists of impure white limestone alternating with bands of marly clay. Its total thickness is 65 to 70 feet. The principal impurities are silica and alumina, which are not excessive, but there are some beds that carry too much magnesia. (See analysis Se 329, p. 314.) This limestone outcrops in low bluffs and on hill slopes in the vicinity of the old cement works northwest of Austin. (See fig. 23, I.)

The Del Rio consists of greenish-blue laminated unctuous clay which weathers brown or yellow. It is rather fossiliferous, containing many seams of calcareous shells, and in places these shells have reacted with ferrous sulphate and formed selenite crystals. This clay lies upon the Georgetown limestone. Its thickness is 80 to 100 feet, but the whole thickness rarely remains except where the clay is protected by the overlying Buda limestone. The outcrop areas of both the Georgetown and the Del Rio formations are narrow. As shown by the analyses (Cy 15 to Cy 25, p. 314), the Del Rio clay is generally rather low in silica as compared to the percentage of iron and alumina, and it also runs high in lime. The best sample of Del Rio clay appears to be Cy 32.

The Eagle Ford clay is composed of laminated bituminous clays, shales, and flaggy limestone. It outcrops in narrow areas northwest of a line drawn northeast-southwest through the middle of Austin. It is usually exposed in low bluffs below a cap of Austin chalk, which is the next higher formation. The total thickness of the Eagle Ford is about 50 feet in the vicinity of Austin. The composition, as shown by analyses Se 361, 364 and 365, approaches that of natural cement rock rather than that of true shale.

The Austin chalk is described on pages 298–299. Analyses Se 335 to 363 indicate that the chalk runs uniformly and moderately high in lime and low in magnesia. The silica is generally in moderate amounts, not too high for the corresponding percentages of alumina and iron oxide.

Overlying the Austin chalk and occupying an outcrop area 3 to 6 miles wide east of the chalk area is a thickness of more than 500 feet of calcareous joint clay or marl. When fresh these beds consist of fine-grained, tough, unctuous blue clay, which quickly becomes laminated and changes to yellow on weathering. This formation is known as the Taylor marl. The material, as shown by analyses Misc. 80 and 81, is neither a natural cement rock nor a good limestone, although it would not require the addition of a large proportion of limestone to bring it up to the composition of a cement mixture.

Next above the Taylor marl is the Webberville formation, which is composed of clay marls with greenish glauconite grains and of black shaly clay with arenaceous layers. Analyses of clay from the Webberville are shown as Cy 26, 27, and 28. This clay is not very uniform in composition, but in places some material fairly high in silica may be found, such as sample Cy 27.

The terrace silt from the south bank of Colorado River is used for making brick at two places. It is calcareous, although less so than most of the so-called shales and clays of the vicinity. Analyses Cy 30 and 31 show respectively a rich clay, used for making dry-pressed face brick, and a loamy clay, used for making soft-mud sand-mold brick.

GENERAL CONCLUSIONS.

Chemical analyses are no longer considered as entirely reliable indices of the true value of raw materials for Portland cement making. They do indicate, however, by comparison with analyses of materials of known value, whether the material in question is worth testing further. In the absence of complete kiln and physical tests, it is not safe to make definite assertions as to the quality of Portland cement that might be made from these materials. It is of interest to note, however, that at Dallas, Tex., good Portland cement is being made from the Austin chalk mixed with Eagle Ford clay, and that at San Antonio Austin chalk is also in use for natural and Portland cements. (See analyses, p. 316.) Austin, an intermediate point on the outcrop of these widespread formations, would thus appear to be favorably situated with respect to these important raw materials. Some years ago cement was made at Austin on a small scale in a vertical kiln from rocks stratigraphically lower than the Austin chalk, namely, the Georgetown limestone and the Del Rio clay. An analysis of seasoned clinker from this kiln (No. 4 of the following table) corresponds closely with the average of ten samples of a mixture of seven standard Portland cements. In 1904 analyses and clinkering tests of limestone and clay from the properties of the Austin Portland Cement Manufacturing Company were made at the laboratories of a large Portland cement company in the North. For purposes of comparison the following analyses are given:

Analyses of raw materials and manufactured cement from Austin, Tex.[a] *(fig. 23, I).*

	SiO_2.	Al_2O_3.	Fe_2O.	CaO.	MgO.	Loss by ignition.
1. Georgetown limestone	5.90	2.90	0.72	49.70	0.20	40.34
2. Del Rio clay	41.68	16.51	2.89	17.10	.20	19.14
3. Resulting cement	20.99	8.81	1.60	68.31	.20	....
4. Old cement clinker	21.44	8.52	3.15	59.44	.36	4.09
5. Typical cement mixture	22.01	6.78	3.21	62.74	2.64	....

[a] Nos. 1, 2, and 3 were made at the laboratory of a working Portland cement plant. Reported by owners of property.
Nos. 4 and 5 made at the laboratories of the U. S. Geol. Survey, St. Louis. Mo.

For the kiln test the limestone (1) and clay (2) were mixed in the proportion of about 3.9 to 1, ground wet to such fineness that practically all the mixture passed a 200-mesh sieve. The mix was dried and burned in a test kiln with gas fuel. The clinker was well sintered and dense and after being finely ground yielded a gray cement having good hardening properties. The results of some of the physical tests were as follows:

Results of physical tests on cement yielded by kiln test on mixed Georgetown limestone and Del Rio clay.

Time of set: Initial, three and one-half hours; final, seven hours.
Specific gravity: 3.12.
Fineness: Passed 100-mesh, 99 per cent; passed 200-mesh, 88 per cent.
Tensile strength, neat: Seven days, 655 to 805; twenty-eight days, 882; one year, 665 pounds per square inch.
Tensile strength, 1:3 sand: Seven days, 425 to 460; twenty-eight days, 471; one year, 375 pounds per square inch.

To be of value for the manufacture of Portland cement shales should contain silica in the proportion of not less than twice nor more than three times the alumina plus the iron oxide, and some manufacturers report best results when the ratio $\frac{SiO_2}{Al_2O_3+Fe_2O_3}$ is between 2.5 and 3.

Inspection of the analyses of all the clays and shales in the table on page 314 shows that in not one of the Del Rio clay samples does this ratio reach as high as 2.5, and in some samples the ratio is less than 2. Only one out of the 20 clays, namely, Cy 28, gives a ratio between 2.5 and 3, although Cy 27 and Cy 32 come close to 2.5. It is evident that these clays should be used in connection with limestones carrying enough silica to make up for the lack of it in the shale. Possibly the necessary silica might be supplied from certain of the more highly siliceous beds in the Georgetown limestone and the Austin chalk. It should be noted that analyses Se 328 and Se 329 show more than the maximum allowable limit of magnesia (MgO), which is generally considered to be 3 per cent. The Austin chalk runs generally higher in lime than the Georgetown limestone and is uniformly low in magnesia. The Eagle Ford clay, according to the analyses, appears to be nearly a natural cement rock, which would require the addition of only a small proportion of high-calcium limestone to make a Portland cement mixture. The Taylor marl is rather high in lime and low in silica, as are most of the samples of Del Rio clay and clay from the Webberville formation. The two terrace clays give ratios much higher than the maximum limit. Se 31 shows a very high percentage of silica, but the writer is not informed as to how much of this is free silica, a very objectionable material. The proportion of alumina and iron oxide is much too low to give promise as a cement material, and the fact that it is so low suggests that a large proportion of the silica does occur in a free state. Attention should be called to the analyses Cy 32 and Cy 27, which seem to have been made upon the most promising samples of clay in the whole series.

ECONOMIC RELATIONS.

For the economical operation of a Portland cement plant in this vicinity operating costs must be kept as low as possible in order to compete with established plants at Dallas, San Antonio, and El Paso, Tex., and also to compete occasionally with eastern cements that are brought by water to Galveston and with cements imported from Germany. It is therefore probably out of the question to consider collecting the limestone and shale from separated localities, although in this way the most suitable combinations of materials might be obtained. The problem resolves itself into one of finding suitable materials adjacent to each other, and of course the more favorably situated with regard to transportation facilities the better. The combinations of adjacent formations that are most logical are Georgetown and Del Rio, Austin and Eagle Ford, and Austin and Taylor. If combinations of materials from any two of these formations are found, on further test, to make good Portland cement, there should be no difficulty in finding ideal manufacturing sites in the vicinity of Austin. All the materials are comparatively soft and it should be possible to grind them very finely without great expenditure of power. Petroleum is the fuel that would probably be most suitable and available in this region. The limestone, clay, and shale that have been mentioned here occur in abundant quantities in the region. Their distribution is shown in detail in the geologic folio (No. 76) on the Austin quadrangle.

ANALYSES.

The analyses in the following table of rocks in the vicinity of Austin that may be of value for making Portland cement were made by P. H. Bates and A. J. Phillips, in the United States Geological Survey structural-materials laboratories at St. Louis, Mo., in 1908. The second table contains analyses of rocks at Dallas and San Antonio, Tex., used for making Portland cement, as well as analyses of the clinker and fresh cement made at Dallas. These data are inserted for purposes of comparison.

Analyses of rocks from vicinity of Austin, Tex., possibly of value for making Portland cement.

Register No.	Material.	Formation.	Thickness sampled.	SiO_2.	Al_2O_3.	Fe_2O_3.	MnO.	CaO.	MgO.	SO_3.	Na_2O.	K_2O.	H_2O at 100° C.	Loss on ignition.	Total.	Ratio: $\frac{SiO_2}{Al_2O_3+Fe_2O_3}$
			Feet.													
Se 322	Limestone	Georgetown limestone	....	11.31	5.89	0.77	0.08	42.86	1.03	Tr.	0.26	0.47	0.51	37.32	100.50	1.70
Se 328	do	do	....	4.32	3.22	.57	.04	40.57	7.63	.12	.10	.10	.28	43.20	100.15	1.11
Se 329	do	do	12	10.39	3.13	1.03	.03	35.09	11.42	.44	....	.24	.49	38.13	100.39	2.49
Se 330	do	do	14	1.38	4.20	.57	.03	49.50	1.77	.13	0.0	.39	.38	41.91	100.26	.29
Se 331	do	do	12	8.09	3.94	.83	.03	46.62	.94	.08	0.0	.39	.75	38.57	100.24	1.69
Se 332	do	do	30	10.33	4.75	1.50	.07	43.25	.69	.06	.05	.67	.41	38.27	100.05	1.47
Cy 15	Clay	Del Rio clay	20	41.20	16.12	3.41	.05	16.36	1.26	.28	.24	1.44	2.32	17.50	100.18	2.11
Cy 16	do	do	20	42.56	15.34	5.28	.04	14.26	1.01	.47	.57	1.21	2.25	17.29	100.28	2.06
Cy 17	do	do	20	40.86	14.92	6.10	.04	14.81	.70	.86	.22	1.48	1.72	18.56	100.27	1.94
Cy 18	do	do	20	38.42	16.95	5.07	.02	14.86	.83	.39	1.04	1.64	2.59	18.59	100.40	1.74
Cy 19	do	do	22	37.64	13.80	6.00	.06	17.18	.79	.48	.72	1.28	2.56	19.86	100.37	1.91
Cy 20	do	do	20	42.10	15.90	3.35	.07	15.33	.36	.82	.23	2.03	2.57	17.37	100.13	2.19
Cy 21	do	do	10	29.48	12.25	2.69	.12	26.32	.82	.07	.16	1.61	2.17	24.61	100.30	1.96
Cy 22	do	do	16	32.91	13.42	2.69	.12	23.61	.97	.92	.15	1.73	1.70	21.98	100.20	2.04
Cy 23	do	do	20	42.09	17.78	2.46	.01	14.24	.98	1.06	1.05	.83	1.96	17.82	100.28	2.08
Cy 24	do	do	10	40.70	15.59	3.24	.07	16.41	.71	.81	.38	1.97	2.21	18.17	100.26	2.15
Cy 25	do	do	17	41.63	15.55	3.57	.07	15.68	.98	.74	.20	1.66	2.97	17.00	100.05	2.17
Se 335	Soft limestone	Austin chalk	....	10.58	5.23	1.24	.04	43.36	1.22	.12	.31	.76	.82	36.46	100.14	1.63
Se 336	do	do	....	8.94	3.00	2.27	.06	45.43	1.19	.14	.27	.45	1.23	37.28	100.27	1.70
Se 337	do	do	1	10.00	3.89	1.53	.04	43.35	1.25	.16	.50	.60	.89	37.75	99.96	1.84
Se 338	do	do	2	9.26	3.59	1.09	.05	44.76	.93	.30	....	.53	1.45	37.83	99.79	1.98
Se 339	do	do	6	5.59	2.33	.93	.06	48.59	.94	.54	.79	.45	.41	39.80	100.43	1.71
Se 340	do	do	4	7.18	3.52	1.24	.03	46.63	1.07	.19	.15	.51	.44	39.32	100.28	1.51
Se 341	do	do	6	5.76	2.70	.47	.03	49.17	.96	.71	.11	.64	.55	39.17	100.27	1.81
Se 342	do	do	....	7.80	4.64	1.14	.02	45.33	1.13	.12	....	.66	1.12	38.10	100.26	1.35
Se 343	do	do	3	6.00	1.50	1.63	.05	48.31	1.15	.24	.17	.55	.37	39.73	99.70	1.91
Se 344	do	do	1.1	6.64	3.55	1.19	.06	47.23	1.26	.18	....	.55	.44	39.12	100.22	1.40
Se 345	do	do	1.6	4.93	1.78	.67	.03	49.38	.87	.13	.71	.12	.52	40.82	99.96	.73
Se 346	do	do	5.5	6.17	2.41	.88	.06	48.55	.91	.08	.06	.49	.35	39.84	99.80	1.87
Se 347	do	do	9.5	2.82	.96	.51	.09	51.39	1.10	.08	....	.22	.36	42.40	99.93	1.95
Se 348	do	do	4.8	6.76	2.83	.67	.03	47.54	.76	.12	....	.40	.47	40.33	99.91	1.93
Se 349	do	do	5.5	4.31	1.89	.52	.03	49.54	.84	.70	.03	.49	.77	40.70	99.82	1.79
Se 350	do	do	7.5	2.28	.57	.56	.04	52.14	1.22	.12	....	.02	.37	42.54	100.17	2.02
Se 351	do	do	8	2.87	1.09	.46	.03	52.49	.85	.10	.17	.24	.23	41.26	99.79	1.85
Se 352	do	do	4.5	3.84	1.31	.47	.03	51.29	1.03	.07	....	.28	.56	40.84	99.72	2.16
Se 353	do	do	10	4.70	1.61	.36	.03	50.01	1.09	.09	.05	.28	.37	41.27	99.86	2.40
Se 354	do	do	19.5	3.12	.92	.26	.03	51.91	.44	.52	....	.16	.20	42.84	100.40	2.64

Se 355	do	do	14.1	9.18	3.50	1.05	.05	45.22	1.13	.14	.17	.55	.67	38.02	100.28	2.02
Se 356	do	do	9	4.30	1.52	.77	.05	50.22	.97	.22	.23	.47	.27	40.88	99.90	1.88
Se 357	do	do	7.5	4.76	1.72	.62	.06	49.79	.88	.10	.06	.46	.43	40.95	99.83	2.03
Se 358	do	do	30+	10.19	3.81	1.14	.03	44.34	1.08	.22	.12	.81	.56	37.54	99.84	2.58
Se 360	do	do		6.17	2.17	.88	.09	48.66	.90	.30	.50	.21	.60	39.39	99.87	2.02
Se 362	do	do	18	5.76	1.19	.82	.01	49.85	1.30	.26		.39	.52	40.48	100.18	2.86
Se 363	do	do	11	3.82	1.30	.72	.02	50.72	1.05	.29	.14	.44	.43	41.17	100.10	1.89
Cy 29	Shaly limestone	do		7.80	2.11	1.38	.01	45.88	.85	.31	.91	1.54	1.24	38.24	100.27	2.24
Misc. 80	Marl	Taylor marl	25	36.08	18.64	4.14	.01	17.39	1.74	1.59	.19	1.49	3.09	15.77	100.13	1.59
Misc. 81	do	do	5	26.18	9.66	3.35	.07	28.15	1.28	1.20	.12	1.06	2.65	26.66	100.38	2.01
Se 361	Clay shale	Eagle Ford clay	15	17.81	6.10	2.04	.02	34.76	1.27	.92	1.60	.50	1.81	32.95	99.78	2.19
Cy 30	Shaly limestone	Pleistocene (?)		50.03	10.25	3.31	.04	13.94	1.70	.05	.54	1.80	1.94	16.48	100.08	3.69
Cy 31	do	do	5 to 15	67.98	7.90	2.27	.03	8.98	1.03	Tr.	.63	1.51	.81	9.07	100.21	6.68
Se 364	Limy shale	Eagle Ford clay	8	17.56	7.60	1.76	.02	32.59	1.28	1.08	.40	1.74	1.82	34.08	99.93	1.87
Se 365	do	do	10	16.30	6.97	1.65	.02	36.03	1.29	.89	.30	1.78	1.81	36.03	99.91	1.89
Cy 32	Clay	Del Rio clay		51.01	18.23	3.51	.02	8.87	1.54	1.03	.08	2.16	2.72	11.04	100.21	2.35
Cy 26	do	Webberville formation		36.28	13.60	1.44	.01	16.42	3.83	.16	.22	.64	7.52	20.07	100.19	2.51
Cy 27	do	do		52.57	15.97	5.23	.03	6.82	2.06	.30	1.17	2.09	4.67	9.53	100.44	2.48
Cy 28	do	do		40.38	18.69	3.62	.03	9.74	3.10	.27	.70	.77	8.21	14.63	100.15	1.89

Se 322 and Se 328 to Se 332. Property of Austin Portland Cement Manufacturing Company, 3½ miles northwest of center of Austin, Tex. (Fig. 23, I.)
Cy 15 to Cy 25. Property of Austin Portland Cement Manufacturing Company, 3½ miles northwest of center of Austin, Tex. (Fig. 23, I.)
Se 335 to Se 358. Big Walnut Creek, 8 miles northeast of center of Austin, Tex., or one-half to 1½ miles northwest of Sprinkle. (Fig. 23, D.)
Se 360. Big Walnut Creek, 9 miles northeast of center of Austin, Tex. (Fig. 23, C.)
Se 362. Lower 18 feet of ledge near mouth of small creek emptying into south side of Colorado River three-fourths mile below concrete bridge. (Fig. 23, Q.)
Se 363. Top 10 or 12 feet of ledge near mouth of small creek emptying into south side of Colorado River three-fourths mile below concrete bridge. (Fig. 23, Q.)
Misc. 80. East bank of Big Walnut Creek 2 miles below Sprinkle, or 6½ miles northeast of Austin, Tex. (Fig. 23, G.)
Misc. 81. Wagon road on hill just west of Little Walnut Creek, 4½ miles northeast of Austin, Tex., or 1 mile north of Pecan Springs. (Fig. 23, J.)
Se 361. South side of Big Walnut Creek 9½ miles northeast of Austin, Tex., or 1⅛ miles below Watters station. (Fig. 23, B.)
Cy 29. Partings from top and middle of 18-foot ledge near mouth of small creek emptying into south side of Colorado River three-fourths mile below concrete bridge. (Fig. 23, Q.)
Cy 30. Heavy calcareous clay used in making dry-pressed brick at Butler's brickyard, south side of Colorado River, near International and Great Northern Railroad. (Fig. 23, N.)
Cy 31. Light loamy clay used in making sand-mold brick at Butler's brickyard, south side of Colorado River, near International and Great Northern Railroad. (Fig. 23, N.)
Se 364. Eight feet of beds below middle of Eagle Ford clay, from bluff of small creek near International and Great Northern Railroad 1 mile south of Colorado River. (Fig. 23, P.)
Se 365. Upper 10 feet of Eagle Ford clay, from bluff of small creek near International and Great Northern Railroad 1 mile south of Colorado River. (Fig. 23, P.)
Cy 32. Bluff of Barton Creek one-third mile above its mouth, sampled above and below wagon road, near bridge. (Fig. 23, M.)
Cy 26 and 27. Wilbarger Creek, 3 miles below Manor. (Fig. 23, H.)
Cy. 28. Moores Branch of Onion Creek, 9 miles southeast of Austin, Tex. (Fig. 23, R.)

Analyses of rocks from Dallas and San Antonio, Tex., used for making Portland cement.[a]

Register No.	Material.	Formation.	Thickness sampled.	SiO_2.	Al_2O_3.	Fe_2O_3.	MnO.	CaO.	MgO.	SO_3.	Na_2O.	K_2O.	H_2O at 100° C.	Loss on ignition.	Total.	Ratio: $\frac{SiO_2}{Al_2O_3+Fe_2O_3}$
			Feet.													
Se 376	Limestone (soft)	Austin chalk	25	6.54	3.22	2.12	0.04	46.72	0.61	0.55	0.38	0.59	0.49	38.64	99.90	1.22
Se 377	do	do	15–20	9.08	4.59	2.23	.11	44.44	.62	.07	.74	.72	.38	36.80	99.78	1.33
D 1	do	do		3.64	2.42			50.92	.46	[b].67				42.10		1.50
D 2	Limestone (shaly)	do		12.78	8.22			40.22	.91	[b].68				36.26		1.55
D 3	Limestone (soft)	do		3.74	2.74			51.11	.58	[b].10				44.70		1.36
D 4	do	do		12.70	8.54			41.33	.62	[b].10				36.02		1.48
Se 378	Shale (top beds)	Eagle Ford clay	8–10	45.07	15.78	4.92	.02	7.98	1.18	9.71	.08	1.70	6.51	6.89	99.84	2.23
Se 379	Shale	do	23	56.71	19.74	5.74	.02	1.28	1.91	.25	.36	1.67	4.00	8.62	100.30	2.53
D 5	Shale (top beds)	do		64.71	20.80	4.15		1.00	.31	[b].72				6.67		2.59
D 6	Shale (bottom)	do		57.74	21.49	7.05		1.66	2.47	[b]1.27				8.11		2.02
D 7	Shale (quarry run)	do		60.09	22.20			2.80		[b].31				12.35		2.70
Ct 711a	Portland cement (clinker)			21.82	11.27	2.59	.06	62.36	.50	.03	.16	.49	.02	.90	100.20	
Ct 711b	Fresh Portland cement			21.35	9.90	1.91	.10	62.78	.72	1.70	.08	.41	.10	1.20	100.25	
SA 1	Limestone (soft, weathered).	Austin chalk	3–5	20.09	2.40	1.20		40.82		[b].07	1.45					5.55
SA 2	Limestone (soft, fresh)	do	3–5	22.90	1.70	0.70		40.77		[b]2.10	2.0					9.54
SA 3	Limestone	do	20+	16.50	6.10	1.00		44.31								2.32
SA 4	do	do	3–5	22.1	2.90			40.82		[b].70						7.62

[a] Analyses Se 376 to Se 379 and Ct 711a and Ct 711b by R. H. Bates and A. J. Phillips, U. S. Geol. Survey laboratories, St. Louis, Mo., 1908; D 1 to D 8 made at laboratory of Texas Portland Cement Company, Dallas, Tex.; SA 1 to SA 4 made at laboratory of Alamo Cement Company, San Antonio, Tex.

[b] Sulphur (S).

Se 376, Se 377, D 1 to D 4, Se 378, Se 379, D 5, D 6, D 7: Quarry of Texas Portland Cement Company, near Dallas, Tex.
Ct 711a, Ct 711b: From new mill of Texas Portland Cement Company, Dallas, Tex., March, 1908.
SA 1 to SA 4: Quarry of Alamo Cement Company, San Antonio, Tex.

BUILDING STONE.

THE SLATES OF ARKANSAS.

By A. H. Purdue.

THE SLATE INDUSTRY IN ARKANSAS.

As early as 1859 a slate quarry was opened in Arkansas, northwest of Little Rock. A company was formed to quarry the slate for roofing purposes, but the product was found incapable of standing the weather. Many years ago a quarry was opened near the mouth of Glazierpeau Creek, 12 miles northwest of Hot Springs, but no reliable report of this slate having been utilized has been obtained. From 1885 to 1908 several quarries were opened up in the western part of Pulaski County and the eastern part of Saline County, and from some of these a small amount of roofing slate has been shipped.

In 1902 the Southwestern Slate and Manufacturing Company was organized to operate in Polk and Montgomery counties. Title was acquired to land to the extent of about 1,600 acres. A large amount of money was subscribed, which was expended in building roads, erecting buildings, installing machinery, and various other improvements necessary for conducting an extensive business when shipping facilities, which were expected soon, could be had. Disappointment in obtaining transportation resulted in the reorganization of the company in 1903. In this reorganization the name was changed and the Southwestern Slate Company, which succeeded to all the property of the first company, purchased 320 acres more of land. The operating plant, located at Slatington, Ark., contains one saw, one planer, and one rubbing bed. To the present time (1910) only milling slate has been produced, a considerable amount of this having been put on the market, principally for electrical uses.

The work of the Southwestern Slate and Manufacturing Company and its successor gave an impetus to slate prospecting. A large number of titles were acquired to slate lands, and more or less prospecting was done on many of them, among which the following are mentioned:

In 1900 the Altus Slate Company opened a quarry in Polk County in sec. 11, T. 3 N., R. 23 W., about 7 miles west of Big Fork post-office. After working for about a year it was discontinued. The writer is informed that no slate was shipped from this quarry. Near by is another quarry that was owned by the Standard Slate Company.

After working for some time this company went into bankruptcy, and the property was sold.

Subsequently the Gulf Slate Company, of Indianapolis, Ind., opened a quarry in sec. 12, T. 3 N., R. 29 W. Some buildings were erected and a good deal of work was done here, but no slate was shipped. Nothing was being done at the time of the writer's visit (summer, 1907).

Near Big Fork post-office there are numerous smaller openings, most of which were made from 1900 to 1906.

In 1904 the J. R. Crowe Coal and Mining Company opened small quarries in sec. 36, T. 3 S., R. 27 W. At the same time small buildings were erected for tenant houses, and a larger one for a hotel. At the time of the writer's visit (1907) no work was being done and no slate had been shipped from this place.

In the winter of 1902 the Ozark Slate Company began operations in Garland County, about 12 miles west of Hot Springs. A plant was erected consisting of a hoisting engine, two wire trams, each about 500 feet long, and a few buildings. The most important of these contained the boiler and engine, two saws, one planer, one band saw, one rubbing bed, and six slate trimmers. A great deal of quarrying was done here. At the time of the writer's visit to this plant (1907) it was in charge of the quarry foreman, but no work was being done.

From 1900 to 1905 a great deal of prospecting was done in Montgomery and Garland counties in the neighborhood of Crystal Springs. About the same time several prospects were opened up farther west, in the vicinity of Plata and Alamo, Montgomery County, but no slate has been shipped from any of these.

THE ORIGIN OF SLATE.

Slate may be defined as any rock in which the property of parting along parallel planes is developed to such an extent that the rock may be split into thin plates with even surfaces. This property of parting is called slaty cleavage.

Slaty cleavage is a secondary property of rocks and is developed in those of fine-grained and soft material. Most such material is of sedimentary origin. It was transported from the land by streams and spread out over the bottom of the sea as mud, in thin layers, one upon the other. Some of these deposits covered wide areas and reached many feet in thickness. In course of time they, with the other rocks above and below them, were elevated into land areas.

Where slaty cleavage was not developed in the course of the elevation the layers in which the mud was spread out have remained in their original condition, except that they generally have been hardened into shale; but where slaty cleavage was developed in the process of elevation all traces of the original layers may have been obliterated. Under such conditions the only partings are those along the cleavage planes. These partings usually are at an angle to the bedding planes and consequently cut across the original mud layers, though in some rocks they are parallel to those layers.

If, in the elevation of a land area, the only forces are those acting in vertical lines, so that the strata remain horizontal, slaty cleavage is not induced; but if there are forces acting horizontally, causing the strata to be folded, slaty cleavage may be developed. It follows that slates do not occur in regions of horizontal rocks; nor can they by any means be expected in all regions of folded rocks.

THE SLATE AREA OF ARKANSAS.

The area of Arkansas in which the surface rocks are folded, and in which consequently slate might be looked for, is in the central-western part of the State (fig. 24). It lies between Arkansas River and the northern parts of Sevier, Howard, Pike, and Clark counties, west of the St. Louis, Iron Mountain and Southern Railroad.

It must not be understood that all parts of this area contain slate; for in the formation of slate not only must dynamic agencies so act upon the rocks as to compress and throw them into folds, but the originally deposited material from which the rocks were formed must have been mechanically and chemically suited to undergo metamorphism into slate. Most slate is metamorphosed shale. Shale is common over all parts of the area mentioned above, and folding in many parts has been so intense as to cause the strata to stand on edge or even to be overturned; yet slate is confined to a comparatively small area, because within that area only were the shales of such a nature as to permit their alteration into slate.

The area in which the slates of Arkansas are situated includes a part of the Ouachita Mountains and extends from the vicinity of Little Rock westward to that of Mena. Its length is about 100 miles and its average width 15 miles. It lies mainly in Saline, Garland, Montgomery, and Polk counties. The St. Louis, Iron Mountain and Southern Railway runs near the eastern border, and the Kansas City Southern Railway near the western border. The Little Rock and Hot Springs branch of the Chicago, Rock Island and Pacific Railway enters the area. The St. Louis, Iron Mountain and Southern Railway has a branch from Malvern to Hot Springs, and the Gurdon and Fort Smith Railroad (not shown on map, fig. 24) is completed from Gurdon to Womble, a new town 2½ miles southeast of Black Springs, Montgomery County.

GEOLOGY OF THE SLATE AREA.

TOPOGRAPHY.

The slate area of Arkansas lies in the southern part of the Ouachita Mountains. The topography is rough and consists of east-west steep-sided ridges, separated by narrow valleys. The slopes of the ridges are covered by loose, angular rocks and by timber. The crests are straight, rock covered, and destitute of timber. The valleys usually

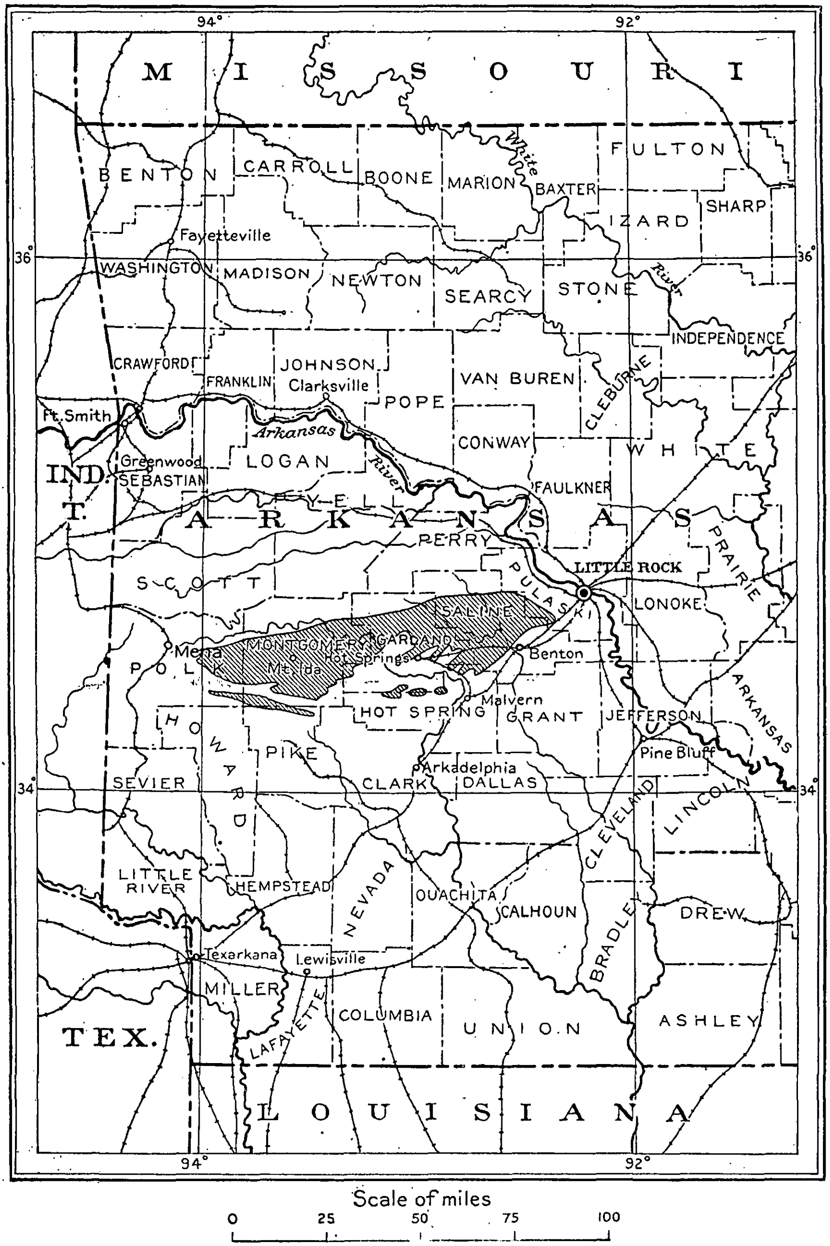


FIGURE 24.—Map showing slate area of Arkansas.

are occupied by small streams, but the master streams, such as Caddo, Little Missouri, and Cossatot rivers, flow southward, cutting through the ridges and receiving the smaller ones along their courses.

ROCKS.

The surface rocks within the slate area of Arkansas are practically all of sedimentary origin. In the eastern part there is a small area of igneous rock at Potash Sulphur Springs, Garland County, and a larger one at Magnet Cove, Hot Spring County. A short distance beyond the eastern border of the slate region there are two small areas of igneous rock. One of these is in Saline County, about 6 miles east of Benton, and the other in Pulaski County, a short distance south of Little Rock. In numerous places throughout the eastern part of the slate area, from the town of Crystal Springs eastward, dikes of igneous rock are reported.[a] These dikes doubtless are of the same age as the larger areas of igneous rock, with which there is good reason to suppose they are connected beneath the surface. Though they are exposed in a large number of places, their actual area is so small and their effect upon the sedimentary rocks so little that for the purpose of the present report they may be dismissed from further consideration.

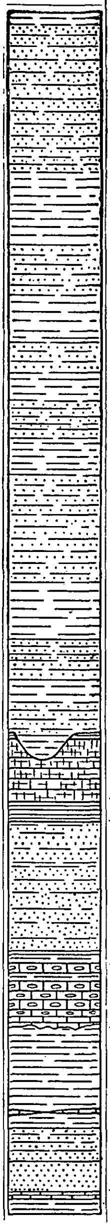
The sedimentary rocks of the area consist of shales and slates, chert, novaculite, sandstone, and a small amount of limestone. Of these the shales and slates occur in the greatest quantity, and the relative amounts of the others are in the order named. The following table presents the different rocks that occur in the area in the order of their age, with the oldest at the bottom:

Section of sedimentary rocks in slate region of Arkansas.

	Feet.
Carboniferous: Stanley shale	6,000
Unconformity.	
Age unknown:	
Fork Mountain slate	100
Arkansas novaculite	800
Missouri Mountain slate	300
Probable unconformity.	
Ordovician:	
Blaylock sandstone	1,500
Polk Creek shale	100
Bigfork chert	700
"Stringtown" shale	100
Unconformity.	
"Ouachita" shale	900
Crystal Mountain sandstone	700
Probable unconformity.	
Age unknown:	
Collier shale (observed thickness)	200
	11,400

[a] Geol. Survey Arkansas, vol. 2, 1890, pp. 409-427.

The columnar section (fig. 25) presents in compact form the age, thickness, and character of the formations.



Period.	Formation.	Columnar section.	Thickness (feet).	Character of rocks.
Carboniferous (Pennsylvanian?).	Stanley shale.		6000	Greenish clay shale, locally black slate near the base, and greenish quartzitic sandstone.
Age unknown.	Fork Mountain slate.		0-125	Gray slate with thin beds of siliceous material.
	Arkansas novaculite.		0-800	Massive white and variegated novaculite with alternating flint and shale layers in the upper half.
	Missouri Mountain slate.		75-300	Mainly red slate with green slate in the basal portion.
Ordovician.	Blaylock sandstone.		0-1500	Greenish quartzitic sandstone alternating with brownish-black shale layers.
	Polk Creek shale.		0(?)-100	Black fissile and sandy graptolitic shale.
	Bigfork chert.		700	Gray to black chert interstratified with black shale layers at the top.
	"Stringtown" shale. "Ouachita" shale.		900-1000	Black graphitic shale, with slaty cleavage, containing sandstone and limestone layers near the base and patches of blue limestone locally conglomeratic near the top.
	Crystal Mountain sandstone.		700	Sandstone interstratified with black shale. Massive, white, coarse-grained sandstone.
Age unknown.	Collier shale.		200+	Black, graphitic clay shale, containing blue conglomeratic limestone near the top.

FIGURE 25.—Columnar section of the Ouachita area.

FOLDING.

That portion of the Ouachita area in which slates occur is intensely folded. In the process of folding there was produced one master anticline, or upward fold, known as the Ouachita anticline.[a] The highest part of this anticline lies between Black Springs, Montgomery County, and Ouachita River in Garland County, passing north of the town of Crystal Springs. Though this anticline pitches to the west in the vicinity of Black Springs, it continues as a marked feature of the structure to the western portion of the State. Upon the north and south slopes of this anticline are numerous smaller folds, which with the main arch form an anticlinorium. An idea of the general structure of the region can be had from figure 26.

The minor anticlines and synclines are comparatively narrow. So intense were the dynamic forces that these folds are closely compressed. The rock layers nearly everywhere stand at a high angle, and in many places they are on edge. Indeed, as a rule the strata not only have been lifted from the horizontal to the vertical position, moving through an arc of 90°, but have been shoved over beyond the vertical position or overturned. This may be seen by reference to figure 26. The over-

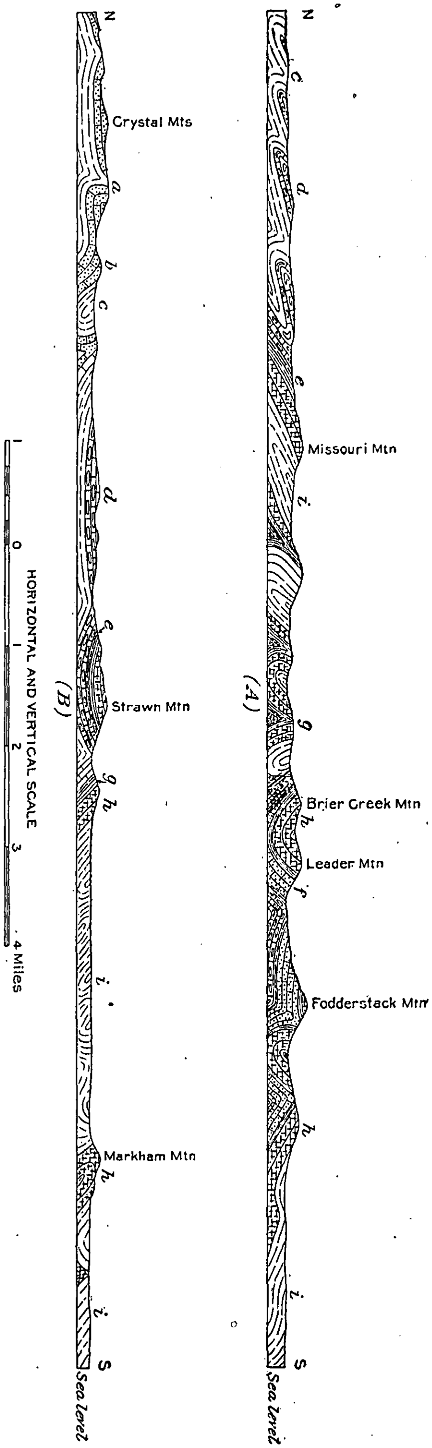


FIGURE 26.—North-south structure sections through the Ouachita Mountains: *A*, Along Polk-Montgomery county line; *B*, through western part of R. 24 W. *a*, Collier shale; *b*, Crystal Mountain sandstone; *c*, "Ouachita" shale and "Stringtown" shale; *d*, Bigfork chert; *e*, Polk Creek shale; *f*, Blaylock sandstone; *g*, Missouri Mountain slate; *h*, Arkansas novaculite; *i*, Stanley shale.

[a] Geol. Survey Arkansas, vol. 3, 1890, pp. 273 et seq.

turning and compression are so complete that the rock layers on either side of the axes of the folds are parallel, forming what are known as isoclines. This produces a repetition of the strata which is confusing to one not familiar with the structure but which must be taken into account by all who intelligently prospect the region for geologic products of any kind.

An idea of the nature of these folds may be obtained from figure 27. The character of the folds by no means persists along their axes but differs within short distances, so that two cross sections of the same mountain only a mile apart would in many cases be different. In other words, the dip of the rocks may differ greatly within short distances. An anticline may break up into two, a symmetrical

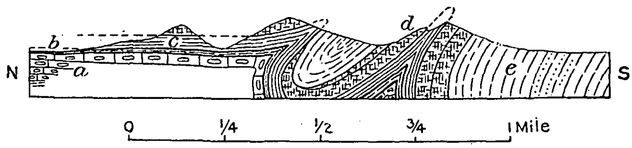


FIGURE 27.—North-south section through Missouri and Statehouse mountains, 1 mile east of Slatington, Montgomery County, Ark. *a*, Bigfork chert; *b*, Polk Creek shale; *c*, Missouri Mountain slate; *d*, Stanley shale.

anticline may pass into an overturn, or an anticline or syncline may sharply pitch or plunge. It is common for two folds to overlap each other laterally, plunging in opposite directions. This structural feature, aided by erosion, produces the zigzag topography so common in the eastern part of the slate area.

FAULTING.

As would be expected, the rocks of the region could not everywhere, by folding, adjust themselves to the great dynamic force exerted upon them, so that thrust faulting is very common. The faults are in the main parallel with the folds. In some places the throw is several hundred feet. These faults have not been worked out in detail over the entire slate area, but among them are several that occur in a faulted belt extending from the valley of Long Creek, south of McKinley Mountain in Polk County, south of east for at least 25 miles, apparently terminating near the main branch of Caddo Creek. In Polk County and the western part of Montgomery County this belt is marked by a single fault, but in the eastern part of range 27 it breaks up into three. Along the line of Bearden, Tweedle, and Reynolds mountains there are two parallel faults.

DESCRIPTION OF THE ARKANSAS SLATES.

Five of the formations of the Ouachita Range contain slate. These are the "Ouachita" shale, the Polk Creek shale, the Missouri Mountain slate, the Fork Mountain slate, and the Stanley shale. Only the last-named three have been prospected to any extent, and most of the prospecting and developing has been done in the Missouri Mountain slate.

"OUACHITA" SHALE.

The "Ouachita" shale is the surface rock about Black Springs and elsewhere in the Caddo Creek basin, Montgomery County. Its area over the Ouachita Range is not known but is greater than the area of all the other slate formations combined. As its name implies, it is mainly a shale, generally showing no indication of slaty cleavage; but in parts of it slaty cleavage is well developed and in such parts is conspicuous in the stream beds, by the roadside, and in other places where the formation is exposed. The cleavage usually is at a high angle to the bedding, and as it appears to be best developed in those parts of the formation where the layers are of different color, "ribbons" are very common in it. These consist of alternating green and blue bands from one-fourth inch to 2 inches thick and are due to original differences in the color of the shale from which the slate was formed. In places this slate is sufficiently indurated for temporary roofing, but generally it is too soft to withstand the weathering agencies long. It is also, in all places where observed, so closely jointed as to prevent the quarrying of blocks of commercial size. Besides, its banded or "ribbon" structure would render it undesirable commercial slate, even though it possessed all the other requisite qualities.

POLK CREEK SHALE.

The Polk Creek shale is only about 100 feet thick, and owing to this fact and to the folded nature of the region it outcrops as narrow belts, which usually are found along the bases of the mountains. This formation, like the Ouachita, is commonly a shale, but locally slaty cleavage is well developed in it. In places this slate is banded, but in others it is of a uniform black color, is hard, has a metallic ring, and contains large numbers of graptolite fossils. Jointing is very common in both the shale and the slate. On account of the comparatively small amount of this formation in which slaty cleavage is well developed and the abundance of the joints, it does not give much promise as a producer of commercial slate; there may, however, be parts from which such slate could be secured.

MISSOURI MOUNTAIN SLATE.

The Missouri Mountain slate is the formation that has been most prospected for slate. Though it does not enter into the minute folding of the region, as does the Polk Creek shale, it partakes of the principal folding. (See fig. 28.) It is widespread over the area, and outcrops in many places near the mountain bases, though it may be found high up on the slopes, or even in notches of the crests of the ridges.

This slate has been rather extensively prospected all the way from Board Camp Creek, in Polk County, eastward to Ouachita River, in Garland County. The point at which it has been most extensively worked is Slatington, Montgomery County, but there are other prospects in it of considerable magnitude. It has been so widely prospected not only on account of its promising character as a source of commercial slate, but because of the favorable location and nature of its outcrops, most of which are in bluffs and well up on the mountain slopes. As the slate is exposed in the face of the bluffs, no labor or expense of removing surface material is imposed upon the prospector; and the height of the outcrop on the slope permits all waste material to be easily dumped. It varies in thickness from about 300 feet to 50 feet or less. The thickest portion is along the central line of the Ouachita Range, from which it thins out southward and probably northward. In some of the closely compressed anticlines it is

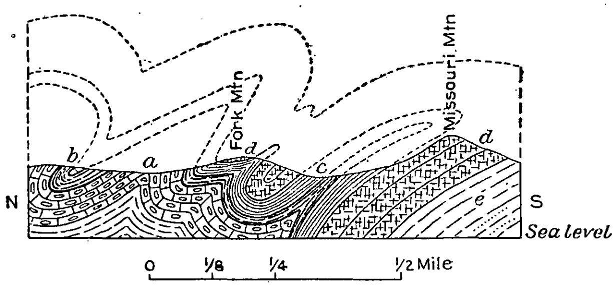


FIGURE 28.—North-south section through Fork Mountain, Arkansas, T. 3 S., R. 28 W., showing the folded nature of the Missouri Mountain slate. *a*, Bigfork chert; *b*, Polk Creek shale; *c*, Missouri Mountain slate; *d*, Arkansas novaculite; *e*, Stanley shale.

folded over upon itself, and in such places its thickness appears to be double what it actually is. Such is the case in that part of Caddo Mountain that lies south of Wagner Creek, in sec. 15, T. 4 S., R. 26 W., where the slate is exposed for 600 feet, lying between heavy walls of the Arkansas novaculite.

The formation produces both red and green slate. Though both kinds may and commonly do occur in the same quarry, the red is predominant. It is a clay slate of remarkable homogeneity, sandy or other impure layers being absent. In color it varies from scarlet to dark red, but that of any particular quarry is likely to be uniform. In exposed surfaces it presents a rich, pleasing appearance. On account of its homogeneous nature, no traces of the original bedding are to be seen. This fact, together with its great thickness, make it impracticable in most places to determine the direction of the cleavage with reference to the bedding planes. In some places where it is near the overlying Arkansas novaculite the cleavage is plainly parallel with the bedding; in other places it is oblique. It is probable that the cleavage usually is oblique to the bedding.

In most parts this slate is intersected by numerous joints that run in all directions, but in favorable places these are not so common as to prevent the quarrying of large blocks. The slate cleaves with fairly even surfaces and can readily be split into sheets a quarter of an inch thick and less. Some parts have a semimetallic ring, but most of it produces a dull sound when struck. In many places the intense folding of the region has produced short, wavelike wrinkles in the slate, which quarrymen call "curl" and which are avoided in prospecting. Any quarry showing a considerable amount of this may as well be abandoned. In other parts two sets of cleavage planes are locally developed. These may be detected by the splitting up of the exposed surfaces into small prisms shaped like shoe pegs. Such exposures as this should be avoided by the prospector.

Sheets of a considerable size are seldom found on the slopes, and hence it appears that this slate weathers readily. If this inference is correct, the slate could not be used for roofing purposes. It is hoped, however, that this statement will not prevent anyone from experimenting with it by putting it into actual use for roofing, as this alone can determine its fitness for such purposes. In the only instance that has come to the writer's attention of shingles of this slate being used for roofing purposes, they went to pieces after a few years' service. But the result of this one trial should not be taken as final, for slate from another quarry might last for many years. The best way to test it is for the people of the slate area to use it on small and temporary outbuildings. Such a test should be made of the slate of every quarry that will produce shingles; for if any of this slate should be discovered with lasting qualities, its beautiful color would at once put it in great demand, especially for buildings with gray walls or trimmings.

At present slate is in demand for inside fittings, such as laundry tubs, wainscoting, lavatories, switchboards, floor tile, etc. This slate is too soft for the last purpose named, but is well adapted for all the other purposes, and especially for switchboards, for which practically all the product of the quarries at Slatington has been used. Several samples of this slate have been tested for conductivity. The result of the tests is published elsewhere in this report (p. 330).

Because of its softness and homogeneity, this is altogether a desirable slate to work. It splits, saws, and planes easily, and soon takes a polish on the rubbing bed. But in the process of drying, after having been taken from the rubbing bed, it is liable to check, and the amount thus lost greatly reduces the profit of working it. This checking is sometimes at right angles to the cleavage and sometimes parallel with it. That is to say, the worked pieces may either crack perpendicularly to their faces, or they may split apart. If some method of working can be devised that will avoid this checking, the slate industry of Arkansas will become an important and profitable one.

FORK MOUNTAIN SLATE.

The Fork Mountain slate lies normally above the Arkansas novaculite, but owing to overturning it commonly lies beneath that formation on the mountain slopes. If on one side of a valley or a ridge it lies above the novaculite, on the opposite side it is most likely to lie below. On account of an unconformity at its top the formation is not everywhere present, and for the same reason it varies greatly in thickness. Its maximum thickness has not yet been ascertained, but in sec. 5, T. 4 S., R. 27 W., where it outcrops well up on the mountain slope, it is known to exceed 100 feet. Where the formation dips into the mountain it can easily be detected, for there it forms bluffs; but where it dips with the mountain slope it may be overlooked.

This is a hard slate, generally gray, though portions of it on weathered surfaces are green or chocolate. Thin sandy or quartzitic layers are numerous. The cleavage usually is well developed and occurs at all angles to the bedding planes. "Ribbons" not uncommonly occur. The slate has great strength and toughness and is highly sonorous. In most places jointing is so common as to render the slate worthless, but it must not yet be concluded that exploiting will find it universally so. Prospectors should not neglect this slate. Though it certainly never would do for milling purposes, if found sufficiently free from joints and sandy seams it would make shingles of exceptional quality.

STANLEY SHALE.

The Stanley shale, as the name implies, is almost everywhere a shale; but in some parts of the closely folded synclines of the Ouachita Range it is altered into true slate. This slate has been rather extensively prospected near Slatington and at several places in the southeastern part of Polk County. It is blue to black in color. The cleavage, where it is best developed, is remarkably fine, permitting the slate to split into very thin sheets with smooth, beautiful surfaces. Except the quarry near Slatington and one east of Bear belonging to the Ozark Slate Company, none of any size has been opened in this formation. Nor has any of the slate, so far as is known to the writer, been used for roofing purposes. From the general observations in the field it appears that this formation does not give much promise of producing commercial slate. Though the formation is a thick one, only a small portion of it has been altered to slate, and this, where observed, is not sufficiently indurated to last long on a roof.

TESTS OF ARKANSAS SLATE.

ELECTRIC TESTS.

Six pieces of red slate from Slatington, Ark., were submitted to W. N. Gladson, professor of electric engineering in the University of Arkansas, who reported the following electric tests:

These pieces of slate were tested in comparison with three pieces of gray slate taken at random from old switch bases in the university electric laboratory. A piece 1 centimeter cube was cut from each sample and these were numbered consecutively from 1 to 9, Nos. 1, 3, and 4 being gray slate. In preparing the cubes metallic particles were found in samples 4 and 6, and Nos. 5 and 6 were so easily split that it was difficult to obtain a centimeter cube.

The pieces of red slate as received were smooth blocks 4 by 5 inches by five-eighths of an inch, neither varnished nor in any way filled. They were red or reddish brown, were much softer than the gray slate, and split much more readily. All samples tested were dry and appeared to be seasoned. The method of measuring the resistance of these centimeter cubes was as follows:

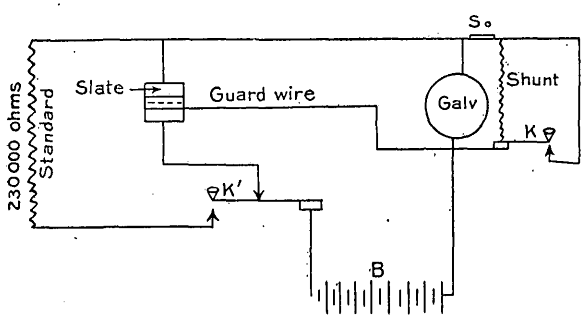


FIGURE 29.—Diagram showing electric connections made in testing slate.

A block of paraffin wax was attached to the center of a glass plate, which in turn was thoroughly insulated from the table by glass strips piled across one another. In the top of the paraffin block an opening was cut 1 centimeter square and about 3 millimeters deep. In the bottom of the cavity thus formed four copper supports were embedded so that their top surfaces were in the same plane, about 1 millimeter below the top of the paraffin cup. A drop of mercury coming about flush with the copper supports in this cavity formed one terminal for making electric connection to the slate cube. Contact with the opposite face was made by placing a well-amalgamated zinc plate 1 centimeter square on top of the cube. This arrangement insured equal contact with each slate cube under test.

The galvanometer used was of the D'Arsonval type, and had a working constant of 70,533 millimeters on the scale 1 meter distant through 1 megohm resistance. The electromotive force was furnished by storage cells and was kept constant at 42 volts during the experiment. The connections were made as shown in figure 29.

To avoid leakage over the surface of the slate a guard wire was connected as shown. All readings were taken after the deflections became constant; in some tests they did not become so until half an hour after electrification.

The results of the test are shown in the following table, from which we find the average resistance of all samples to be 1,224.2 megohms per cubic centimeter. The average resistance of the three gray samples was 1,180, and of the six red-slate samples 1,267.8 megohms per cubic centimeter. Each piece tested, except No. 7, shows a different resistance between each pair of opposite parallel faces, which seems to depend on the plane of cleavage. The gray-slate samples show a decidedly higher resistance between faces of cubes perpendicular to cleavage planes, but in individual samples the distribution of resistance would be greatly affected by the presence of foreign conducting particles or seams, which are likely to be present in all slate.

Results of tests of electric resistance of slate samples.

Sample No.	Galvanometer scale deflections.			Resistance.[a]		
	Perpendicular to cleavage planes.	Parallel to cleavage planes.		Perpendicular to cleavage planes.	Parallel to cleavage planes.	
	D.	D′.	D″.	R.	R′.	R″.
	Mm.	*Mm.*	*Mm.*	*Megohms.*	*Megohms.*	*Megohms.*
1	39.0	40.0	44.0	1,808.5	1,763.3	1,603.0
2	98.0	174.0	625.0	719.7	405.3	67.1
3	171.0	185.0	283.0	414.9	381.2	249.2
4	35.0	94.0	43.0	2,015.3	750.4	1,640.3
5	104.0	47.7	39.9	678.2	1,476.3	1,767.1
6	338.9	28.0	88.0	208.1	2,519.0	801.5
7	91.0	91.0	48.0	775.0	775.0	1,469.4
8	57.0	51.0	27.0	1,500.7	1,383.0	2,612.3
9	45.0	33.0	36.0	1,567.4	2,137.3	1,959.2

[a] R, R′, and R″ correspond to the directions D, D′, and D″, respectively.

Average of Nos. 1, 3, and 4 (gray slate), 1,180.6 megohms per centimeter cube.
Average of Nos. 2, 5, 6, 7, 8, and 9 (red slate), 1,267.8 megohms per centimeter cube.
Average of all samples, 1,224.2 megohms per centimeter cube.

PHYSICAL AND CHEMICAL TESTS.

The following specimens were collected and submitted to the structural-materials testing laboratories of the United States Geological Survey at Forest Park, St. Louis, Mo., for transverse pressure, absorption, and physical tests, and for chemical analyses. The results are herewith published:

Source and color of slate samples tested.

No.	Owner.	Locality.	Color.
1	Southwestern Slate Co	E. line of NE. ¼ SE. ¼ sec. 33, T. 3 S., R. 27 W	Red.
2	do	do	Green.
3	M. J. Harrington	Sec. 24, T. 3 S., R. 29 W	Black.
4	Southwestern Slate Co	SE. ¼ SE. ¼ sec. 33, T. 3 S., R. 27 W	Red.
5	M. J. Harrington	Sec. 24, T. 3 S., R. 29 W	Black.
6	M. W. Jones	do	Green.
7	do	do	Do.
8	do	do	Red.
9	do	do	Reddish brown.
10	do	do	Red.
11	C. B. Baker	NE. ¼ sec. 18, T. 3 S., R. 28 W	Buff.
13	M. W. Jones	Sec. 24, T. 3 S., R. 29 W	Red.

Results of physical tests on Arkansas slate.

Field No.	Register No.	Individual specimen No.	Transverse tests.							Absorption tests.						Specific gravity.		Absolute porosity $1\frac{\text{A.s.g.}}{\text{T.s.g.}}$	Weight per cubic foot.
			Dimensions.		Span.	Conditions at maximum load.			Modulus of elasticity (constant nearly to maximum).	Weight ratio of absorption.			Volume ratio of absorption.						
			Width.	Depth.		Load at center.	Deflection at center.	Modulus of rupture.		30 minutes.	24 hours.	48 hours.	30 minutes.	24 hours.	48 hours.	True.	Apparent.		
			Inches.	*Inches.*	*Inches.*	*Pounds.*	*Inches.*	*Lbs. per sq. inch.*											*Pounds.*
1	Misc. 141	1	2.00	0.95	9	322	0.0190	2,410	2,100,000	0.0017	0.0189	0.0189	0.0047	0.0511	0.0513	2.863	2.714	....	169.1
		2	1.98	.97	9	674	.0148	4,880	4,640,000	.0005	.0175	.0193	.0014	.0475	.0523	2.859	2.712	....	169.0
		3	1.98	.98	9	854	.0196	6,060	4,250,000	.0011	.0164	.0786	.0031	.0439	.0500	....	2.689	....	167.5
		Av.	....	....	....	....	....	4,450	3,660,000	.0011	.0176	.0189	.0031	.0475	.0512	2.861	2.705	0.0545	168.5
2	Misc. 142	1	1.94	1.00	9	920	.0134	6,400	6,430,000	.0004	.0089	.0105	.0010	.0243	.0286	2.813	2.738	....	170.6
		2	1.97	.98	9	959	.0150	6,840	6,040,000	.0004	.0075	.0095	.0012	.0205	.0260	2.816	2.747	....	171.1
		3	1.99	.97	9	920	.0170	6,630	5,470,000	.0003	.0087	.0101	.0009	.0238	.0276	....	2.744	....	171.0
		Av.	....	....	....	....	....	6,620	5,980,000	.0004	.0084	.0100	.0010	.0229	.0274	2.815	2.743	.0256	170.9
3	Misc. 143	1	1.98	.28	12	59	.0430	6,840	13,420,000	.0037	.0160	.0189	.0094	.0409	.0481	2.696	2.550	....	158.9
		2	1.95	.26	12	56	.0790	7,640	8,820,000	.0012	.0114	.0146	.0031	.0293	.0375	2.702	2.564	....	159.7
		3	2.05	.27	12	80	.0855	9,640	11,030,000	.0041	.0167	.0201	.0105	.0425	.0512	....	2.544	....	158.5
		Av.	....	....	....	....	....	8,040	11,090,000	.0030	.0147	.0179	.0077	.0376	.0456	2.699	2.553	.0541	159.0
4	Misc. 144	1	2.07	.30	12	93	.0600	8,990	11,820,000	.0026	.0113	.0121	.0072	.0310	.0332	2.862	2.748	....	171.2
		2	1.98	.27	12	64	.0560	7,980	12,420,000	.0009	.0087	.0114	.0025	.0241	.0315	2.857	2.776	....	173.0
		3	1.99	.29	12	80	.0615	8,600	11,570,000	.0013	.0112	.0122	.0036	.0307	.0334	....	2.741	....	170.8
		Av.	....	....	....	....	....	8,520	11,940,000	.0016	.0104	.0119	.0044	.0286	.0327	2.860	2.755	.0367	171.7
5	Misc. 145	1	1.94	.85	12	210	....	2,700	2,900,000	.0023	.0120	.0157	.0058	.0305	.0402	2.705	2.557	....	159.3
		2	2.04	.77	12	279	.0405	4,150	3,150,000	.0033	.0153	.0193	.0083	.0390	.0491	2.704	2.544	....	158.5
		3	1.94	.78	12	388	.0335	5,920	6,010,000	.0024	.0121	.0156	.0062	.0309	.0397	....	2.553	....	159.1
		Av.	....	....	....	....	....	4,260	4,020,000	.0027	.0131	.0169	.0068	.0335	.0430	2.705	2.551	.0570	159.0
6	Misc. 146	1	2.04	1.09	12	400	.0252	2,970	2,620,000	.0014	.0076	.0114	.0040	.0210	.0314	2.860	2.771	....	172.6
		2	2.03	1.02	12	318	.0134	2,710	4,810,000	.0010	.0081	.0093	.0027	.0225	.0257	2.854	2.767	....	172.4
		3	2.03	1.01	12	791	.0233	6,880	6,920,000	.0015	.0080	.0093	.0041	.0221	.0257	....	2.769	....	172.5
		Av.	....	....	....	....	....	4,190	4,780,000	.0013	.0079	.0100	.0036	.0219	.0276	2.857	2.769	.0308	172.5
7	Misc. 147	1	2.03	.24	12	35	.0660	5,390	9,240,000	.0010	.0089	.0109	.0028	.0243	.0300	2.805	2.739	....	170.6
		2	2.07	.23	12	57	....	9,370	10,290,000	.0013	.0089	.0107	....	....	....	2.810	....	....	....
		3	1.96	.24	12	40	.0740	6,380	8,060,000	.0011	.0090	.0113	.0029	.0246	.0310	....	2.733	....	170.3
		Av.	....	....	....	....	....	7,050	9,200,000	.0011	.0089	.0110	.0029	.0245	.0305	2.808	2.736	.0256	170.5
9	Misc. 149	1	1.99	.17	7	48	.0317	8,760	13,150,000	.0010	.0073	.0088	.0029	.0203	.0244	2.849	2.764	....	172.2
		2	2.00	.14	7	47	.0358	12,590	19,530,000	.0010	.0081	.0091	.0029	.0227	.0256	2.845	2.806	....	174.8
		3	2.00	.22	4	120	....	7,440	....	.0009	.0082	.0091	.0026	.0229	.0255	....	2.789	....	173.8
		Av.	....	....	....	....	....	9,600	16,340,000	.0010	.0079	.0090	.0028	.0220	.0252	2.847	2.786	.0214	173.6

11	Misc. 150..	1	1.97	.53	9	139	.0181	3,390	4,720,000	.0183	.0410	.0410	.0467	.1045	.1045	2.828	2.552	....	159.0
		2	1.94	.51	9	155	.0181	4,150	6,090,000	.0185	.0402	.0404	.0471	.1023	.1029	2.830	2.546	....	158.6
		3	1.93	.52	9	140	.0206	3,620	4,500,000	.0084	.0365	.0365	.0216	.0941	.0941	....	2.576	....	160.5
		Av.	....	....	....	....	....	3,720	5,100,000	.0151	.0392	.0393	.0385	.1003	.1005	2.829	2.558	.0958	159.4
8	Misc. 148..	1	1.94	.15	7	20	.0265	4,810	9,820,000	.0016	.0094	.0101	.0045	.0263	.0283	2.863	2.801	....	174.5
		2	2.04	.17	7	36	.0330	6,410	9,410,000	.0010	.0081	.0096	.0028	.0227	.0272	2.866	2.822	....	175.8
		3	2.02	.17	7	32	.0250	5,760	15,810,000	.0010	.0089	.0098	.0027	.0252	.0279	....	2.838	....	176.8
		Av.	....	....	....	....	....	5,660	11,680,000	.0012	.0088	.0098	.0033	.0247	.0278	2.865	2.820	.0157	175.7
10	Misc. 148..	1	1.99	.12	7	9.75	.0430	3,570	5,730,000	.0088	.0251	....	....	....	....	2.854	....	....	....
		2	1.93	.13	7	8	.0378	2,570	4,250,000	.0072	.0257	.0257	.0194	.0689	.0689	2.857	2.682	....	167.1
		3	1.97	.14	7	18	.0440	4,890	6,340,000	.0067	.0251	.0253	.0180	.0672	.0677	....	2.676	....	166.7
		Av.	....	....	....	....	....	3,680	5,440,000	.0076	.0253	.0255	.0187	.0681	.0683	2.856	2.679	.0620	166.9
13	Misc. 148..	1	2.03	.15	6	20	.0440	3,940	3,550,000	.0046	.0228	.0229	.0124	.0613	.0617	2.862	2.691	....	167.6
		2	2.00	.16	6	20	.0300	3,520	4,420,000	.0062	.0243	.0243	.0167	.0652	.0652	2.860	2.683	....	167.1
		3	1.93	.18	6	24	.0180	3,450	6,480,000	.0061	.0241	.0244	.0163	.0640	.0648	....	2.658	....	165.6
		Av.	....	....	....	....	....	3,640	4,820,000	.0056	.0237	.0239	.0151	.0635	.0639	2.861	2.677	.0643	166.8

NOTE.—Specific gravities corrected at 70° F.

Chemical analyses of slate samples.

	1.	2.	3.	4.	5.	6.	7.	8, 10, 13.	9.	11.
Silica	53.81	54.83	68.90	57.79	69.76	52.50	55.71	53.23	52.35	52.79
Alumina	25.40	23.53	14.03	22.92	14.16	26.31	25.20	26.29	26.16	24.96
Ferric oxide	6.17	5.06	(a)	5.19	(a)	3.98	2.46	3.81	5.81	6.27
Manganese oxide	.06	.14	.02	.07	.04	.11	.11	.06	.10	.06
Lime	.31	.28	.37	.23	.38	.28	.26	.31	.29	.28
Magnesia	1.74	3.05	1.11	1.97	1.32	2.27	1.74	1.87	2.29	1.69
Sulphuric anhydride	Tr.	.26	.56	.08	.07	.22	Tr.	Tr.	Tr.	Tr.
Ferrous oxide	2.75	3.41	4.65	2.62	4.58	5.34	3.97	4.21	3.16	3.81
Sodium oxide	.49	.21	.05	.12	.13	.04	.22	Tr.	.16	.03
Potassium oxide	4.27	3.21	2.14	4.66	1.94	3.32	4.51	3.58	3.82	3.52
Water at 100° C	.66	.43	.66	.48	.54	.47	.53	.59	.57	.72
Ignition loss	4.62	6.01	7.69	4.13	7.44	5.33	5.13	5.82	5.19	5.79
	100.28	100.42	100.18	100.26	100.36	100.17	99.84	99.77	99.90	99.92

[a] Owing to the large amount of volatile organic material it is impossible to determine the ferrous oxide, consequently all iron has been assumed as being present in the lowest state and calculated as such.

THE OOLITIC LIMESTONE INDUSTRY AT BEDFORD AND BLOOMINGTON, INDIANA.[a]

By Jon A. Udden.

LOCATION AND AREA.

The building stone here considered is known by different trade names, as "Bedford stone," "Bedford oolitic limestone," "Indiana limestone," and "Indiana oolitic limestone." It is used extensively in the construction of government, municipal, and private buildings. It is quarried in south-central Indiana, principally in Lawrence, Monroe, and Owen counties. The two most active centers of stone production are Bedford, in Lawrence County, and Bloomington, in Monroe County. These counties are considered to be in the heart of the building-stone region, which in this vicinity averages in width about 3 miles east and west; but the stone is more widely distributed, extending nearly 150 miles north and south from Parkersburg, in the southern part of Montgomery County, to Ohio River, and from 2 to 14 miles east and west.

The pioneers in developing the building-stone industry were Davis Harrison and Nathaniel Hall, who opened the Blue Hole quarry, about 1 mile east of Bedford, toward the close of the fifties. Since then the number of openings has increased so that at the present time about 125 sites may be observed of quarries that are either in actual operation or have been abandoned.

GEOLOGY.

The geology of this region is rather simple. The rocks comprise unconsolidated deposits of Quaternary age and hard rocks of Mississippian age. The Quaternary deposits consist of glacial till and drift,

[a] For discussions of the geology of the oolitic limestone in Indiana the reader is referred to the following papers by Hopkins and Siebenthal and Ashley, and for greater detail regarding some of the quarries to the paper by Blatchley.

Hopkins, T. C., and Siebenthal, C. E., The Bedford oolitic limestone: Twenty-first Ann. Rept. Indiana Dept. Geology and Nat. Res., 1896, pp. 291–427.

Ashley, G. H., Geology of the lower Carboniferous area in southern Indiana: Twenty-seventh Ann. Rept. Indiana Dept. Geology and Nat. Res., 1903, pp. 49–122.

Blatchley, R. S., The Indiana oolitic limestone industry in 1907: Thirty-second Ann. Rept. Indiana Dept. Geology and Nat. Res., 1908, pp. 301–459.

lacustrine and terrace deposits, and alluvial flood plains. The hard rocks of Mississippian age that outcrop in Lawrence, Monroe, and Owen counties consist of the following, named in the order of age:

Chester group.
Mitchell limestone.
Spergen limestone (known to the trade as Bedford limestone).
Harrodsburg limestone.
"Knobstone" group.

The contacts between these formations as observed in this region are very sharp. The contact between the Spergen limestone (Bedford oolitic stone) and the Mitchell limestone is particularly sharp.

In a geologic sense the name "Bedford" limestone has been replaced by Spergen limestone, because of the conflict of the name Bedford with the well-established term Bedford shale of the Carboniferous of Ohio.

The rocks in this region have a general dip to the southwest, amounting to 50 or 60 feet to the mile; there are no other notable structural features. The physiographic features in this area are in part controlled by the dip of the strata, which has aided in the initial direction of the drainage, and in part by the resisting or nonresisting character of the various formations to erosion and disintegration, which has given rise to various topographic features, such as knobs, ridges, wide and narrow valleys, sink holes, and subterranean drainage.

The most interesting formations are the Spergen and Mitchell limestones. All the stone used as a building stone is obtained from the Spergen and crushed stone is supplied by the Mitchell, which in many places has to be removed before the building stone can be obtained. The Spergen (Bedford oolitic) limestone outcrops in nearly all the stream valleys, and the outcrops vary in thickness from 25 to 100 feet. It is because of this physiographic feature that nearly all the quarries are located in or adjacent to the valleys. Another factor that has aided in the location of quarries is the thickness of the overlying Mitchell limestone. Where erosion and disintegration have continued a long time a great deal of the overlying Mitchell limestone has been removed, and at these places the early quarries were located. At present a great number of these quarries have exhausted their easily accessible supply of stone, and now in order to carry on operations it has become necessary to remove from 30 to 40 feet of the Mitchell limestone.

ECONOMIC DATA.

QUARRIES.

Two steps are necessary in preparation of the stone for construction work—first, the quarrying of the stone; second, the milling of the raw material. Two concerns therefore handle the stone, the quarry company and the stone-mill company. Some of these concerns are independent of one another, but most of them are closely associated.

The whole region has been subdivided into districts, partly according to the quality of the stone, partly to the prominence of the locality, and partly to the quantity of the stone produced. There are in all 14 districts, situated as follows: In Lawrence County, Peerless, Buff Ridge, Reed Station, Dark Hollow, Spider Creek, Bedford, and Rock Lick districts; in Monroe County, Stinesville, Elletsville, Hunter Valley, Bloomington, Sanders, and Belt or Clear Creek districts; in Owen County, Romona district.

The quarries differ greatly in size; the largest in operation at present are in the Buff Ridge, Clear Creek, and Romona districts. The largest quarries in the Buff Ridge district are operated by the Perry-Mathews-Buskirk Stone Company and the Bedford Quarries Company; in the Clear Creek district, by the National Stone Company, the Chicago-Bloomington Stone Company, and the Monroe County Stone Company; in the Romona district, by the Romona Oolitic Stone Company. The first two districts were visited, and a description of one of the largest quarries will serve as an illustration of the character and equipments of quarries in this region.

This quarry is situated in the Buff Ridge district, on a tract of 160 acres of land, 80 acres of which contains good building stone. Up to the present about 40 acres of this has been quarried by several openings more or less separated from one another.

Over a greater portion of this quarry a considerable amount of stripping is necessary, consisting of clay up to 5 feet thick and limestone. This is especially true of the west and north workings, where as much as 35 feet of Mitchell limestone has to be removed. Most of this is quarried by drilling and blasting and removed by a steam shovel, then loaded into cars or dumped into old workings. The clayey material is generally removed by means of scrapers.

After the overburden has been removed the stone is ready to be quarried. The thickness of the stone suitable for a first-class building material ranges from 45 to 70 feet, though stone 70 feet thick is uncommon. The greater part of this consists of a buff-colored stone, but in the lower portions of the quarry the blue stone predominates.

The equipment for quarrying the stone at this place consists of 45 channeling machines of the Sullivan, Ingersol, Wardwell, and New Albany types, and 25 derricks. Some of the derricks are operated by steam and some by hand. Generally a derrick is so placed that it will handle the stone obtained from an area about 125 feet square, and two or three channeling machines are used in the same area.

The stone, after it has been channeled, loosened, and cut into desired lengths, is hoisted from the pits and placed on flat cars, a part of the stone being shipped directly to the mill and a part retained in order to be reduced to a uniform size at the quarry by a machine known as a scabbling machine. The function of this machine is to reduce the stone to somewhat even blocks, in order to lower the cost of shipment of quarry blocks to distant points. The machine consists of a set of cast-steel gearing, so arranged as to revolve two heavy disks in opposite directions and also to move a traveling table or platen beneath them. The disks are 2 inches thick and 3 feet in diameter. They are perforated so as to permit the introduction of pointed steel teeth, three on each disk, so set that those of one disk correspond to those of the other. The first pair are 1 inch shorter than the following pair. The third pair are 2 inches longer than the second pair. Thus on one revolution stone to a depth of 3 inches is cut from the block. The last pair of teeth are finishers.

The cutting of these teeth by a circular motion gives the block face a grilled surface. The disks revolve always one way, the teeth on one disk operating downward at the top of the block and the teeth in the opposite disk acting upward at the bottom of the block.

The machinery used at the quarries does not vary a great deal and is less complicated than the machinery used in the stone mills. In the process of stripping the equipment depends greatly upon the nature of the material to be removed—whether it is clay or stone. Where there is an abundance of clay it may be removed by either a wet process (hydraulicking) or a dry process (by means of scrapers). Where there is an abundance of limestone in the overburden it is necessary to use steam drills and powder. The material after it has been blasted out is removed either by steam shovels or by hauling in wagons.

In quarrying the building stone either single or double acting channeling machines of the following types are used: Wardwell, Ingersol, New Albany, and Sullivan. The Wardwell machine is used more extensively than any other, principally because it was the first machine to be used in the stone region. The stone is quarried in blocks 30 to 40 feet long, 8 to 10 feet wide, and 6 to 10 feet thick. In order to reduce these larger blocks, small steam drills of the Ingersol "Baby Giant" type are used in many quarries. Hoisting derricks are in part constructed of wood, but recently steel derricks have been introduced. The derricks are operated either by steam, by electricity, or by hand. Where steam is used, three or four derricks are usually operated by one man.

In some of the pits where no natural drainage is to be had pumps are kept in operation to remove the surface water.

MILLS.

At Bedford there are 16 mills engaged in producing finished Bedford oolitic limestone. The largest stone mills in operation are those of the Furst-Kerber Cut Stone Company and the Bedford Quarries Company. Most of the mills purchase rough stone either from the Perry-Mathews-Buskirk Stone Company or from the Bedford Quarries Company. Some of the mills operate their own quarries, but during the past year these have been idle, because rough stone could be purchased from the Perry-Mathews-Buskirk Stone Company and the Bedford Quarries Company at a lower price than the cost at the other quarries.

The various mills in operation at Bedford are the following: (1) Furst-Kerber Cut Stone Company, general offices, 443 Fifth avenue, Chicago, Ill.; (2) J. P. Falt Company, general offices, Springfield, Ohio; (3) Bedford Cut Stone Company, Bedford, Ind.; (4) Climax Stone Company, Bedford, Ind.; (5) John A. Rowe Cut Stone Company, Bedford, Ind.; (6) Indiana Cut Stone Company; (7) Ingalls Cut Stone Company, general offices, Binghamton, N. Y.; (8) Hann Mill; (9) Shea & Donnelly, general offices, Lynn, Mass.; (10) Bedford Steam Stone Works, Bedford, Ind.; (11) Brook Cut Stone Company, Bedford, Ind.; (12) Perry-Mathews-Buskirk Stone Company, Chicago, Ill.; (13) Henry Struble Cut Stone Company; (14) Dugan Cut Stone Company; (15) Giberson Cut Stone Company; (16) Bedford Stone and Construction Company, Indianapolis, Ind.

At present the largest mill producing finished stone ready to be placed in a building is equipped as follows: The building, covering an area 500 feet long and 165 feet wide, is provided with modern machinery. During the winter months this building is heated by hot air and during the summer months cooled by a large fan. The building is lighted by electricity. On an average about 130 men are employed during the year. The equipment for producing a finished stone consists of the following machinery: Six steel-blade gang saws; two diamond saw machines, one a single circular saw, 74 inches in diameter, in which there are 168 diamonds, operated by belt from a shaft, and the other a double circular saw 100 inches in diameter, each saw containing 180 diamonds, operated by an individual motor; nine planers, seven of which are double platen planers, one a single platen planer, and one a circular planer; the largest planer will accommodate a stone 16 feet 8 inches by 8 feet 4 inches by 4 feet 2 inches; two headers; five lathes, the largest of which will turn out a stone 30 by 8 feet; six electric traveling cranes, of 3, 3, 5, 15, 30, and 110 ton capacity. A compressed-air machine is used for pneumatic tooling and for light drilling.

The average annual output of finished stone at this mill amounts to about 200,000 cubic feet. The greater portion of the rough stone that was bought cost, on an average, during 1909, 25 cents a cubic foot.

It is understood among local concerns that a company operating both quarry and mill and at the same time selling stone to various other companies may not produce a finished stone for building purposes. This agreement, however, does not seem to be universally observed.

At Bloomington there are five stone mills producing finished stone, located along the Illinois Central and the Chicago, Indianapolis, and Louisville railroads. The Central Oolitic Stone Company (17) is located in the northern part of Bloomington, and the South Side Stone Company (18), James H. Nolan & Sons (19), the Hoadley Cut Stone Company (20), and the Bloomington Cut Stone Company (21) are located in the southern part of Bloomington.

The equipment in the various mills depends greatly on the contracts obtainable by each individual company. The machinery used is, however, the same, and consists generally of one or more gang saws, planers, either single or double platen, circular planers, headers, lathes, diamond saws, either circular or horizontal, and pneumatic tools. To convey the stone from point to point either steam or electric traveling cranes are used, but in some places derricks serve this purpose. The machines in use in the mills at Bedford and Bloomington are summed up in the following table, in which the numbers at the top correspond to those given to the different plants in the lists above and on page 339.

Summary of equipment of stone mills at Bedford and Bloomington, Ind.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	Total.
Gang saws	1	6	2	1	...	2	3	6	8	1	21	3	2	4	6	6	6	3	...	4	2	87
Planers	6	2	2	4	9	5	6	4	4	2	5	5	3	3	8	3	3	2	2	4	2	84
Headers	1	...	...	...	2	1	...	1	1	1	1	1	1	...	...	1	1	...	...	...	2	14
Lathes	2	1	...	...	5	1	...	1	3	...	4	...	...	...	1	...	2	1	...	3	...	24
Diamond saws	1	...	1	1	2	2	1	...	1	...	1	1	1	...	3	...	1	1	1	2	1	20
Traveling cranes	3	1	1	2	6	2	3	3	3	1	5	3	2	2	5	2	1	...	1	2	...	48
Air compressors	...	...	1	1	1	1	...	...	1	...	1	1	1	...	1	...	...	...	...	1	...	10

WASTE AND ITS UTILIZATION.

During the processes involved in quarrying and in preparing the stone for its final use a large quantity of material is wasted. The waste is in part caused by peculiarities of the stone, by its handling, and in part by the designers' ideas in ornamental construction. Waste may be considered, first, as it occurs in the quarries, and, second, as it occurs in the mills.

The waste occurring in the quarries may be due to various factors, such as the quantity and the character of the overburden, the color of the stone, irregularities in the stone known as stylolites or "crow's feet," joints, the texture of the stone, and quarry practice in general.

Where there is a comparatively thick overburden to be removed there is less waste than where the overburden is thin or lacking. The tendency of the greater thickness of overburden is to protect the desired stone from the action of percolating waters, which if unchecked tend to form solution channels. The absence of these channels is noticeable particularly in some of the workings of the Perry-Mathews-Buskirk quarry, where an overburden 30 feet thick has to be removed. The effect of a thin overburden is well illustrated in the quarries of the Bedford Quarries Company and likewise in nearly all of the quarries south of Bloomington. In these quarries the surface of the Bedford oolitic stone is very irregular, because of the solvent action of surface waters; besides, there are numerous solution channels filled with clay, 3 to 4 feet wide and 10 to 12 feet deep, and even greater.

The Bedford oolitic stone is blue or buff in color; originally probably all the stone was blue. The change in the color of the stone is due in part to a chemical reaction by which ferrous compounds present in the stone are oxidized to ferric oxide, partly by oxygen present in the ground water. The line of demarcation between blue and buff is very sharp and irregular. The occurrence of the two colors in the same block of stone lessens the price, so that stone of this character is usually considered as waste.

Structural irregularities known as stylolites or "crow's feet" and "toe nails" cause considerable waste in places, perhaps as much as 3 to 5 feet on either side of the stylolite. These are, however, not abundant, and generally in a quarry not more than two are encountered in the entire thickness of the stone. Some joints cause considerable waste, especially where the overburden has been very thin, allowing surface waters to follow their course so as to form solution channels. Where these are numerous it is difficult to quarry blocks of suitable size, and moreover the color of the stone along these places is very irregular.

The texture of the Bedford oolitic stone is granular, varying from a very fine to a coarsely granular stone. When extremely fine or coarse stone is obtained it is discarded, because the former is too expensive to work and the latter can not generally be sold. In places small crystals of calcite occur in cavities or along fractures known as "glass seams," and generally stone in which these are encountered has to be rejected.

In quarrying the stone there is always a certain amount of waste due to the channeling machines, to irregularity in the breaking of blocks, to scabbling the stone either by hand or machine, and to other mechanical means used in obtaining the stone. Considering all of these various ways in which a stone may be spoiled it is estimated that in the quarries the total quantity of waste varies between

35 and 50 per cent. The great proportion of waste may be clearly appreciated by observation of the immense grout piles in and around all quarries.

In the mill the quantity of waste is not so large as in the quarries; nevertheless the percentage is comparatively high, considering that choice blocks of stone are always used. Various mill operators estimate that in the mills the waste amounts to 20 to 25 per cent The waste is principally in planer and lathe work where large columns and various trimmings for buildings are made.

Most of the stone rejected in the quarries is dumped into old workings or into large grout piles and is never used.

Practically no attempts have been made by the quarrymen themselves to use the rejected stone. At present, however, the waste is used to some extent in making lime and as a flux. At the Perry-Mathews-Buskirk Stone Company's quarry the rejected stone is being used to some extent by the Ohio Western Lime and Cement Company. In making lime the equipment for burning consists of three kilns of stone and two cylindrical steel kilns, four of these being in continual operation. About 120 barrels of lime is burned in each kiln daily. The greater part of the output is shipped to the waterworks at Cincinnati, Ohio.

The waste from the various stone mills is used by the Illinois Steel Company as a flux; the entire waste occurring in each plant is generally loaded into cars and is paid for at 15 cents a ton.

There are no crushing plants in operation at the quarries in either Bedford or Bloomington. It seems as if it should be possible to make use of the rejected stone, provided low freight rates could be had, so that crushed stone could be furnished to the surrounding towns. The Mitchell limestone, which overlies the Spergen ("Bedford") limestone, is a hard, generally fine-grained and durable stone, and it would be suitable for crushed stone. This material could no doubt be used to advantage in concrete work as well as in road construction. Besides the Mitchell limestone stripping, the rejected blocks of building stone could be used to advantage as crushed stone.

Both the Mitchell limestone and the Bedford oolitic limestone have been used in and around Bedford and Bloomington in the construction of highways, small local quarries having been opened for that purpose.

PORTLAND CEMENT MATERIALS.

The possibility of using the rejected stone in the manufacture of cement has not yet received very much consideration.

A Portland cement plant is operated by the United States Cement Company about 1½ miles southeast of the Lawrence County courthouse at Bedford, on the east side of the Baltimore and Ohio Railroad. A new quarry was opened, although stone equal to the material now being used could have been had at any of the larger quarries and with a less amount of labor. The rock used in the manufacture of the cement is Mitchell limestone. The quarry from which the limestone is obtained is situated about 900 feet east of the crusher plant. This limestone varies in thickness from 30 to 55 feet and consists of a fine to coarse grained dark-blue stone. About 15 feet above the level of the quarry floor there is a ledge of grayish shaly limestone, reported to be high in magnesium, which varies in thickness from almost nothing to 4½ feet.

Analyses of limestone obtained on the premises show the following composition:

Analyses of Mitchell limestone from Bedford, Ind.

	1.	2.		1.	2.
SiO_2	0.94	1.20	$CaCO_3$	97.28	92.20
Fe_2O_3	.54	.78	$MgCO_3$	.98	.68

The shale used in the manufacture of the cement is shipped in from pits operated by the same company at Brownstown, Ind. The cost of transporting the shale from Brownstown to Bedford amounts to 50 cents a ton. The chemical composition of this clay varies, as observed in the following analyses:

Analyses of shale from Brownstown, Ind.

	1.	2.	3.	4.	5.	6.	7.
SiO_2	61.92	59.00	58.20	59.24	66.90	61.56	66.66
Al_2O_3	19.03	21.50	21.60	20.46	22.90	27.00	25.7
Fe_2O_3	6.33	7.01	7.60	7.18	....	....	....

The mixture at present used consists of 12,000 pounds of limestone to about 3,100 pounds of shale.

LABOR CONDITIONS AND WAGES.

In both Bedford and Bloomington there is usually a shortage of men for both the quarries and the mills. This is especially true in the quarries, where all of the work has to be carried on in the open and the working days are dependent on weather conditions. In the mills, where nearly all of the work is carried on under cover, there is less trouble in keeping men. On an average laborers in quarries receive about $1.50 a day. In the stone mills the wages range from 62½ cents down to 15 cents an hour and average about 26 cents. The carvers are the best paid and the other operatives rank somewhat in the following order: Stonecutters, plane men, blacksmiths, traveling runners, head sawyers, head hookers, tool grinders, car blockers, sawyers, hookers, assistant tool grinders, mill laborers, and wire-saw men.

SHIPPING FACILITIES AND RATES.

Both Bloomington and Bedford are favored with transportation facilities. The railroads entering this region are the Illinois Central, the Chicago, Indianapolis and Louisville, the Indiana Southern, and the Baltimore and Ohio Southwestern, besides some local lines which handle the stone between the quarries and railroads.

The freight rates in effect during 1909 are of interest as showing the consistent rates enjoyed by the Bedford stone between different parts of the United States. Freight rates on 100 pounds of stone from the Bedford district to points in Indiana range from 3 to 12 cents. The rates to points outside of Indiana range from 6 cents per hundred to Louisville, Ky., up to 64 cents per hundred to San Francisco and Seattle. The rate to Chicago is 11 cents; to Kansas City it is 21 cents; to Denver, 35 cents; to St. Paul, 18 cents; to New Orleans, 20 cents; to Atlanta, 19 cents; to New York, 28 cents; and to Boston, 30 cents.

COMMERCIAL VALUE OF BEDFORD OOLITIC STONE.

The price of stone varies considerably, especially when the color of the stone is taken into consideration. Rough quarry blocks, either buff or blue, known as A-1 stone, quarried around Bedford, sold during 1909 for 25 cents a cubic foot. The same stone in scabbled blocks sold for 30 cents a cubic foot. Buff or blue stone quarried at Bloomington sold during 1909 for 18 or 20 cents a cubic foot. There is still another grade of stone known as "mixed stone" which has both a buff and a blue color. Stone of this grade is the cheapest and sells for 8 cents a cubic foot. The price of this grade of stone is essentially the same at Bloomington and Bedford. As soon as the stone has to be put through various other processes it increases in price, and the price varies greatly, depending on the amount of work that has to be done on the stone.

The price of sawed stone is as follows at Bedford:

Price per cubic foot of sawed stone at Bedford, Ind.

	Cents.
Sawed on two sides, buff or blue stone	35
Sawed on four sides, buff or blue stone	50
Sawed on two sides, mixed stone	15
Sawed on four sides, mixed stone	23

The prices on stone at Bloomington when sawed are usually 10 to 15 cents a cubic foot less than at Bedford. This difference is due to the fact that the rough stone can be had at a lower price than at Bedford. The greatest cost pertains to stone on which there is a great deal of fancy carving or on which considerable planer or lathe work has to be undertaken.

COMPARATIVE STATISTICS OF STONE PRODUCTION.

During the last ten years the total value of all building stone produced in the United States amounted to $49,270,771. The total value of all the building stone produced during this time in Indiana amounted to $20,912,028 and in Missouri to $4,691,047. The combined value of the stone produced in Indiana and Missouri amounted to $25,603,075, or approximately 51.96 per cent of the total value of the stone produced in the United States. During this time approximately 42.44 per cent of the total value was produced in Indiana and 9.52 per cent in Missouri. In the following table is given the value of all building stone produced in the United States, in Indiana, and in Missouri during each of the last ten years:

Value of building-stone production in the United States, Indiana, and Missouri.

Year.	United States.	Indiana.	Missouri.
1899	$5,075,158	$1,400,854	$242,469
1900	4,330,706	1,639,985	362,344
1901	5,219,310	2,123,237	377,146
1902	5,563,034	1,813,577	429,115
1903	4,981,241	1,880,561	447,884
1904	4,543,760	2,059,386	410,918
1905	5,312,183	2,492,960	580,835
1906	5,098,631	2,636,421	690,625
1907	4,580,226	2,378,008	538,114
1908	4,566,522	2,487,039	603,597
	49,270,771	20,912,028	4,691,047

SUPPLEMENTARY NOTES ON THE GRANITES OF NEW HAMPSHIRE.

By T. Nelson Dale.

INTRODUCTION.

The granites and granite quarries of Concord, Milford, and Redstone, N. H., were described in a former bulletin.[a] During the summer of 1909 the remaining active granite quarries of New Hampshire were visited as well as a few idle ones. The results of these observations and studies are here given. The treatment of the subject, as in Bulletins 313, 354, and 404, on the other New England granites, is both scientific and economic.

The words "coarse," "medium," and "fine," as applied to granite, are to be understood as in those bulletins: *Coarse*, with feldspars over 0.4 inch; *medium*, with those under 0.4 and over 0.2 inch; *fine*, with those under 0.2 inch.

As in the bulletins referred to, the number of each specimen described, to which that of one or more thin sections corresponds, is given so that the descriptions can be verified by consulting the collections at the National Museum.

All the granites here described, as well as the other New Hampshire granites described in Bulletin 354, will be found commercially classified and scientifically determined in the table on pages 370–371, which is thus complete for this State. The total number of quarries is 49.

The local or trade names of the granites have no geologic significance.

Dr. Albert Johannsen, of the United States Geological Survey, has critically revised the more difficult petrographic determinations.

LOCATION OF THE QUARRIES.

The quarries are in the towns of Fitzwilliam, Marlboro, and Troy, in Cheshire County; Kilkenny and Stark, in Coos County; Canaan, Haverhill, and Lebanon, in Grafton County; Brookline, Manchester, and Nashua, in Hillsboro County; Allenstown and Hooksett, in Merrimack County; Rochester, in Strafford County; and Sunapee, in Sullivan County.

[a] Dale, T. Nelson, The chief commercial granites of Massachusetts, New Hampshire, and Rhode Island: Bull. U. S. Geol. Survey No. 354, 1908; New Hampshire, pp. 144–188.

GENERAL PETROGRAPHIC CHARACTER OF THE GRANITES.

The granites of these quarries fall into nine petrographic groups:

Fine quartz monzonite (Brookline).

Coarse biotite granite gneiss (Canaan and Lebanon).

Medium-grained gray biotite granite (Manchester and Rochester).

Medium-grained pinkish biotite granite (Stark).

Fine bluish-gray granites with both muscovite and biotite in varying proportions, exceptionally with porphyritic texture (Troy, Marlboro, Fitzwilliam, Sunapee).

Fine biotite-muscovite granite (gray or pinkish) with sparse large porphyritic feldspars (Briar Hill, Haverhill).

Medium-grained muscovite-biotite granite (Allenstown and Hooksett).

Muscovite-biotite gray granite gneiss (Nashua).

Augite-biotite granite, olive-green on exposure (Kilkenny).

GEOLOGIC OBSERVATIONS AT THE QUARRIES.

INCLUSIONS AND CONTACTS.

On the east side of the Perry quarry near Lake Sunapee (pp. 368–369) are two inclusions of quartz-mica diorite gneiss. The larger, 10 feet long and of very irregular outline, is crossed by meandering quartz veins. These inclusions appear to lie not within the fine granite of the quarry but within a coarser granitic rock adjoining or crossing it. The diorite consists of andesine, biotite, quartz, and titanite. Back of the northeast corner of the quarry is another inclusion of a similar rock, but with some hornblende. These diorites resemble that described in Bulletin 354, page 187. A disused quarry of that rock occurs a little north of the Perry light-granite quarry. A coarse porphyritic granite occurs also on the same hillock. A little west of Sunapee on the road to Newport a coarse porphyritic granite, a fine-grained granite, and a dark schistose rock all occur in a single outcrop. The relations of the diorite gneiss to the fine and the coarse granite were not further investigated.

The quartz monzonite at the O'Rourke quarry in Brookline (p. 361) contains inclusions up to 6 by 3 feet of quartz-mica diorite gneiss, consisting of quartz, biotite, and oligoclase-andesine to andesine.

The quartz monzonite at the Fessenden quarry at South Brookline (p. 362), which lies a mile south-southwest of the O'Rourke quarry, contains inclusions of coarse banded biotite gneiss (with lenticular feldspars) up to 20 by 9 inches. The chief feldspar is orthoclase with a little microcline; the other is oligoclase. The size and number of the inclusions at a disused opening here points to the proximity of the gneiss capping.

The biotite granite of the Bodwell and Kennard Ledge quarries at Manchester (pp. 363–364) appears as narrow dikes intruding a quartz-mica diorite gneiss varying much in texture and crossed by pegmatite dikes. At the Kennard ledge quarry the dike strikes north but the gneiss foliation nearly east. At the Bodwell quarry there are tongues and inclusions of this gneiss in the granite.

DISCOLORED GRANITE ADJACENT TO BASIC DIKE.

The light-gray muscovite-biotite granite at the Bailey quarry in Allenstown (pp. 365–366) is crossed by a hornblende diabase dike 3 to 4 feet thick. The granite for 14 feet on one side and 2 feet on the other has become medium greenish gray owing to the slight chloritization of its plagioclase.

PEGMATITE DIKES.

The pegmatite dikes at the Bailey quarry, referred to above, contain black tourmaline and beryl. A thick dike of coarse garnetiferous pegmatite in the center of the Marlboro quarry has a border made up largely of beryl and its biotite is in blades a foot long and 1 inch wide. This dike is reported to have yielded a garnet crystal over 6 inches in diameter and beryls of the same length. The pegmatite dikes of the Perry Sunapee quarry contain the usual black tourmaline and garnets.

THE GRANITES AND QUARRIES.

The granite and quarry descriptions are arranged alphabetically by counties and townships.

CHESHIRE COUNTY.

WEBB FITZWILLIAM QUARRY.

The Webb Fitzwilliam quarry is one-half mile south of Fitzwilliam Depot, in Fitzwilliam Township. (See map of Monadnock quadrangle, U. S. Geol. Survey.) Operator, Webb Granite and Construction Company, 40 Crescent street, Worcester, Mass.

The granite (specimen D, XXX, 66, a), "Fitzwilliam Webb," is a muscovite-biotite granite of light, very bluish gray color and of even-grained fine texture, with feldspars and micas under 0.2 inch. Its constituents, in descending order of abundance, are: Clear bluish to translucent potash feldspar (microcline and orthoclase), slightly kaolinized; clear colorless quartz with cavities and hairlike crystals of rutile; clear to milk-white soda-lime feldspar (oligoclase), some of it slightly kaolinized and micacized; muscovite (white mica) in large scales; and biotite (black mica) in more abundant and much smaller scales. Accessory: Magnetite (very little), apatite, rutile. Secondary: Kaolin, a white mica. No effervescence with cold dilute muriatic acid.

The quarry, opened before 1829, measures about 1,300 feet in a N. 50° E. direction by 200 feet in width for half of its length and by 250 feet for the rest, and from 6 to 35 feet in depth. The stripping consists of 18 inches of loam.

The sheets are 6 inches thick at the top and 3 feet at the bottom, the greater part, however, being thin ones. They dip 15° NW. at the northwest side but turn, dipping northeast on the northeast side of the hill. The general structure of the hill is thus that of either a dome or an anticline. There are only five joints. Set (*a*) of four joints, near the northeast end of the quarry, strikes N. 20° W., dips 90° or steep east or west, and is spaced 5, 20, and 100 feet. The (*b*) joint, near the southwest end of the quarry, strikes N. 40° E. and dips 70° N. 50° W. The rift is reported as striking N. 55° E. and dipping 35°–40° N. 35° W., and the grain as dipping 80° S. 35° E. In working the rock is split along the grain. Many dikes of garnetiferous pegmatite, from an inch to 2 feet thick, strike north or north-northwest and dip 90° or 20° E. In places the pegmatite is associated with aplite. Small aplite dikes, 1 to 2 feet apart, strike east. All these dikes throw considerable stone into the second class. No rusty stain nor segregations were observed.

The plant comprises three derricks (30 and 40 ton), three hoisting engines, a 10-ton traveling crane, an air compressor (capacity 700 cubic feet of air per minute), three large rock drills, 12 air-plug drills, and a steam pump.

Transportation is effected by a 7,000-foot siding to Fitzwilliam Depot, besides 1,500 feet of subsidiary siding in the quarry.

The product is used mainly for buildings and monuments. Specimens: City hall, Newark, N. J.; approaches and base of First Church of Christ, Scientist, Boston. The smaller sheets are used for paving.

SILVER WHITE QUARRY.

The Silver White quarry is one-fourth mile northeast of Fitzwilliam Depot, in Fitzwilliam Township. (See map of Monadnock quadrangle, U. S. Geol. Survey.) Operator, Perry White Granite Company, Keene, N. H.

The granite (specimens D, XXX, 68, a, b), "Silver White," is a biotite-muscovite granite of light bluish-gray color and of even-grained, very fine texture with feldspars under 0.1 inch and micas to about 0.05 inch. Its constituents, in descending order of abundance, are: Clear bluish to translucent potash feldspar (orthoclase and microcline); very light smoky quartz with cavities and hairlike crystals of rutile; clear to milk-white soda-lime feldspar (oligoclase), very little kaolinized, some small mica crystals; biotite (black mica);

muscovite (white mica). Accessory: Rutile. Secondary: Kaolin, calcite. Effervesces slightly with muriatic acid test. Polished face shows neither pyrite nor magnetite.

An estimate of the mineral percentages by the application of the Rosiwal method to a camera lucida drawing of a thin section enlarged 40 diameters yields these results with a mesh of 1.8 and a total linear length of 43.2 inches:

Estimated mineral percentages in Fitzwilliam granite from the Silver White quarry.

Quartz		43.66
Potash feldspar (microcline and orthoclase)	32.22	45.74
Soda-lime feldspar (oligoclase)	13.52	
Black mica (biotite)	5.88	10.60
White mica (muscovite)	4.72	
		100.00

The average diameter of the particles, obtained from the same calculation, is 0.00668 inch.

Prof. Leonard P. Kinnicutt, of the Worcester Polytechnic Institute, by a test made December 11, 1908, for the Norcross Brothers Company in Worcester, found that 100 pounds of Fitzwilliam granite quarried by the Perry White Granite Company at this or the Snow Flake quarry absorbed 0.382 pound of water.

This is a delicate bluish-gray fine-grained stone, well adapted for fine work. Its particles are so fine and its minerals so evenly distributed that aside from a fine mottling, visible only near by, its color is uniform. It takes a good polish.

The quarry, opened about 1904, is about 300 feet square and 40 feet deep. The stripping is 10 feet thick and mostly of weathered granite.

The sheets consist of short lenses at the surface, but are not well marked below. The quarry is probably near the lower limit of sheet structure. There are no joints, but here and there a fracture crosses one sheet only. One such fracture strikes N. 40° E. and dips 60° N. 50° W. The rift is reported as horizontal and the grain as vertical, with a nearly east-west course. Pegmatite dikes up to 1 foot thick strike N. 30° W. and N. 60° W. with steep dips. Biotitic segregations are rare and up to 4 inches across. There is little or no rusty stain on sheet surfaces.

The plant of this combined with that of the Snow Flake quarry of the same firm comprises two 15-ton and two 40-ton derricks, four hoisting engines, two air compressors (capacity 1,500 and 525 feet of air per minute), three large rock drills, a hollow steel deep-hole drill (1½ inches by 6 feet), besides the following at the cutting shed: A 10-ton and a 5-ton derrick, three surfacers, and twenty air hand tools.

Transportation is by siding to Fitzwilliam Depot.

The product is used for buildings and monuments. Specimens: Smith mausoleum, Paducah, Ky.; Tanner mausoleum, Springfield, Ill.; Heywood Brothers building, Gardner, Mass. Certain buildings are enumerated below under the product of the Snow Flake quarry as built partly of the granite of this quarry.

SNOW FLAKE QUARRY.

The Snow Flake quarry is two-fifths of a mile northeast of Fitzwilliam Depot and three-fourths of a mile south of Fitzwilliam village, in Fitzwilliam Township. (See map of Monadnock quadrangle, U. S. Geol. Survey.) Operator, Perry White Granite Company, Keene, N. H.

The granite (specimen D, XXX, 67, a), "Snow Flake," is a biotite-muscovite granite of light inclining to medium gray shade and of porphyritic texture, with fine matrix (micas under 0.1 inch) and feldspars to 0.5 inch. Its constituents, in descending order of abundance, are: Faintly greenish clear potash feldspar (microcline in twins with crush borders, also orthoclase), some of the microcline intergrown with quartz, some slightly kaolinized; light smoky quartz with cavities, generally in sheets, and hairlike crystals of rutile; clear to milk-white soda-lime feldspar (oligoclase-albite), some of it minutely intergrown with quartz (vermicular structure), some of it a little kaolinized; biotite (black mica); and muscovite (white mica). Accessory: Apatite, zircon, rutile. Secondary: Kaolin, limonite from biotite. No effervescence with muriatic acid test.

The fineness of the mica deprives the stone of strong contrasts and the porphyritic texture is discernible only on close inspection.

The quarry, opened between 1885 and 1887, is about 300 feet square and 40 to 70 feet deep. The stripping consists of 3 to 10 feet of clay and bowlders.

The sheets, 10 to 20 feet thick, are about horizontal but irregular. There is but one joint. The rift is reported as horizontal and the grain as vertical, with about east-west course.

The plant has been described with that of the preceding quarry.

Transportation is by siding to Fitzwilliam Depot.

The product is used for buildings and monuments. Specimen: Flagstaff monument, class of 1878, Lehigh University, South Bethlehem, Pa. The following are of the combined product of this and the Silver White quarry: Art museum, Toledo, Ohio; law building of University of Iowa, Iowa City; post-offices at Muskegon, Mich., Chippewa Falls, Wis., Grand Island, Nebr., Decatur, Ill., Bedford, Ind., Mayfield, Ky., Devils Lake, N. Dak., Allentown, Pa., and Ithaca, N. Y.; and Wysong residence, corner Seventy-sixth street and Fifth avenue, New York.

HOLMAN QUARRY.

The Holman quarry is 1½ miles southeast of Fitzwilliam village and as far east-northeast of Fitzwilliam Depot. (See map of Monadnock quadrangle, U. S. Geol. Survey.) Operator, E. B. Holman, Fitzwilliam Depot, N. H.

The granite (specimen D, XXX, 71, a), "Fitzwilliam," is a muscovite-biotite granite of light bluish-gray color and of even-grained medium inclining to fine texture, with feldspars under 0.3 inch and mica under 0.1 inch. Its constituents, in descending order of abundance, are: Clear bluish potash feldspar (microcline and orthoclase) intergrown with quartz, circular in cross section; clear, colorless quartz with cavities, some in sheets, and hairlike crystals of rutile; milky soda-lime feldspar (oligoclase), some of it kaolinized and micacized; muscovite (white mica); biotite (black mica). Accessory: Magnetite (very little), apatite, rutile. Secondary: Kaolin, a white mica, calcite. The stone effervesces slightly with muriatic acid test.

The quarry, opened in 1909, is about 20 feet square and 12 feet deep. The stripping consists of 2 feet of clay and bowlders.

The sheets, insufficiently exposed, are probably up to 10 feet thick. One joint and heading on the south side strikes N. 80 W., vertical. The rift is reported as horizontal and the grain as vertical, with east-west course. There are two half-inch pegmatite dikes. Discoloration is 2 inches thick on sheet surfaces.

The plant consists of one horse derrick.

Transportation is by cartage of 1¼ miles to siding of Boston and Maine Railroad.

The product thus far has been used for local monuments.

MARLBORO QUARRY.

The Marlboro quarry is 1¼ miles north-northeast of Webb station (Marlboro Depot), in Marlboro Township. (See map of Monadnock quadrangle, U. S. Geol. Survey.) Operator, Webb Granite and Construction Company, 40 Crescent street, Worcester, Mass.

The granite (specimen D, XXX, 69, a), "Marlboro," is a biotite-muscovite granite of light inclining to medium, very bluish gray color, and of even-grained fine texture, with feldspars and micas to 0.2 inch. Its constituents, in descending order of abundance, are: Clear bluish to translucent potash feldspar (microcline), intergrown with quartz, circular in cross section and slightly kaolinized; clear, colorless quartz with cavities in sheets and hairlike crystals of rutile; milk-white soda-lime feldspar (oligoclase), some whatkaolinized and with small plates of muscovite; biotite (black mica); muscovite (white mica). Accessory: Apatite, zircon, rutile. Secondary: Kaolin, calcite. The stone effervesces with muriatic acid test.

The quarry, opened before 1849, was originally about 950 feet long by about 700 feet wide but now measures about 750 feet in a north-northeast direction by 200 feet across and averages 50 feet in depth.

The sheets, 6 inches to 6 feet thick, but not over 2 feet in the upper half of the quarry, are normal and horizontal, but dip low north-northeast at the north end of the quarry and turn to dip low south-southwest at the south end. The thinness of the sheets and the compressive strain prevents channeling, so dynamite is used. Two vertical joints near the north end, with N. 60° E. strike, extend off and on for 50 feet. On the extreme east side a joint striking N. 50° E. and dipping 50° NW. extends only 100 feet. Flow structure is very marked on sheet surfaces at the west side. It consists of alternately more or less biotitic planes striking N. 30° E. but also curving, varying much in width and resembling a gneiss foliation. On the east side flow structure has a N. 30°-40° E. course. There is an inclusion or an irregular biotitic flowage band, 4½ feet long, 1 foot wide, and oval in cross section. The rift is reported as horizontal and the grain as vertical, with N. 22° E. course. A thick pegmatite dike crosses the center of the quarry with N. 55° W. course and dip of 30°-45° N. 35° E. There are smaller pegmatite dikes and streaks of like course in the northern half of the quarry. There is no rusty stain on sheet surfaces.

The plant comprises five derricks (20 to 50 ton), five hoisting engines, a 10-ton traveling crane, a locomotive, an air compressor (capacity 700 cubic feet of air per minute), three large rock drills, 32 plug drills, and a steam pump, besides a stone crusher with screens of 2-inch, 1½-inch, and ¾-inch meshes and a capacity of 200 tons per day.

Transportation is effected by 4 miles of siding from Webb station.

The product is used mainly for buildings, curbing, and paving. Specimens: The lower seven stories of the Marshall Field building, Chicago; First Congregational Church, Nashua; and soldiers' monument, Fitzwilliam village, N. H.

TROY QUARRY.

The Troy quarry is three-fourths of a mile east-southeast of Troy station, in Troy Township. (See map of Monadnock quadrangle, U. S. Geol. Survey.) Operator, Troy White Granite Company, Worcester, Mass.

The granite (specimen D, XXX, 70, a), "Troy white," is a muscovite-biotite granite of light inclining to medium bluish-gray color and of even-grained fine texture, with feldspars under 0.2 inch and mica to 0.1 inch. Its constituents, in descending order of abundance, are: Clear bluish potash feldspar (microcline, generally in twins, intergrown with quartz, circular in cross section, also orthoclase); clear, colorless quartz with hairlike crystals of rutile and cavities in sheets; milk-white soda-lime feldspar (oligoclase-albite), some of it minutely intergrown with quartz, generally kaolinized and a little micacized, and with calcite; muscovite (white mica); biotite (black mica), some of it chloritized. Accessory: Magnetite (very little), pyrite, apatite, rutile. Secondary: Calcite, a white mica, chlorite.

An estimate of the mineral percentages by the application of the Rosiwal method to a camera lucida drawing of a thin section, enlarged 25 diameters, yields these results with a mesh of 1 inch and a total linear length of 59 inches, from which, however, areas of mixed particles too fine for measurement and having a total linear length of 18.28 inches had to be deducted, leaving as the total length of measured particles 40.72 inches:

Estimated mineral percentages in Troy granite.

Quartz		44.94
Potash feldspar (microline and orthoclase)	31.23	44.29
Soda-lime feldspar (oligoclase-albite)	13.06	
White mica (muscovite)	8.25	10.77
Black mica (biotite)	2.52	
		100.00

The following analysis, made for the operators by Prof. L. P. Kinnicutt, of the Worcester Polytechnic Institute, in 1891, is given here for reference:

Analysis of Troy white granite.

SiO_2 (silica)	73.15
Al_2O_3 (alumina)	17.04
CaO (lime)	.81
MgO (magnesia)	.30
K_2O (potash)	5.74
Na_2O (soda)	2.05
Loss and undetermined	.91
	100.00

Professor Kinnicutt, by a test made for the operators December 11, 1908, found that 100 pounds of this granite absorbs 0.269 pound of water, as compared with 0.371 pound for the same weight of Concord granite and 0.420 pound for 100 pounds of quartz monzonite from the New Westerly quarry at Milford, N. H.[a]

The following compression test on a 6-inch cube was made at the United States arsenal at Watertown, Mass., on April 15, 1891 (No. 7419): First crack at 525,000 pounds, total pounds 630,100. Ultimate strength per square inch, 17,950 pounds.

[a] See Bull. U. S. Geol. Survey No. 354, 1908, pp. 173, 174.

This stone is harder than many granites. It lends itself well to fine carving, as is shown by the garland of roses so finely executed by Joseph Carabelli, of New York, on the Hawgood monument at Lake View Cemetery, Cleveland, Ohio.

The quarry, opened about 1859, measures about 300 feet in a N. 15° E. direction by 180 feet across and from 50 to 70 feet in depth. The stripping consists of 15 feet of clay and loam.

The sheets, 6 inches to 15 feet thick, dip 10°–15° W. There are two sets of joints—(*a*), striking N. 77° W., dipping 65° S. 13° W.; (*b*), striking about north, one only, on the east wall. The rift is reported as horizontal and the grain as vertical with N. 15° E. course. There are biotitic segregations up to 2 inches in diameter. Rusty stain is generally absent, but one sheet surface showed 6 inches of it. An east-west compressive strain is noticeable.

In quarrying channeling is done on two sides along the grain, and powder or wedges are used along the hardway.

The plant comprises four derricks of 8, 10, 25, and 50 tons, five hoisting engines, an air compressor (capacity 100 cubic feet of air per minute) run by a 20-horsepower engine, four large steam drills, five air-plug drills, four air hand tools, and two steam pumps.

Transportation is effected by an electric siding, 4,230 feet long, operated by a 40-horsepower gasoline engine.

The product is used about equally for buildings and monuments. Specimens: Worcester County Institution for Savings, Worcester, Mass.; Bank of Pittsburg, Pittsburg, Pa.; Howard Savings Institution, Newark, N. J.; Metropolitan Savings Bank, Baltimore; steps and approaches to Library of Congress, Washington; steps and approaches to New York Library; Hawgood monument and Mark Hanna mausoleum, Lake View Cemetery, Cleveland, Ohio; James Lister monument, Swan Point Cemetery, Providence, R. I.; Albert Wyckoff mausoleum, Woodlawn Cemetery, New York.

COOS COUNTY.

KILKENNY QUARRY.

The Kilkenny quarry is in Kilkenny Township, about 19 miles N. 28° W. from the top of Mount Washington and about 5 miles N. 79° E. from Lancaster station and 940 feet above it, on the southwest side of a ridge. The quarry has been idle for several years.

The granite (specimen D, XXX, 73, b), "Kilkenny," is an augite-biotite granite of dark olive-green color, a little lighter than the green granite of Mount Ascutney, Vt., and considerably darker than the green granite of Redstone, N. H., and Rockport, Mass.[a] It becomes lighter, that is, more yellowish brown, on continued exposure. The

[a] See Bull. U. S. Geol. Survey No. 404, 1909, pp. 116, 117, and Bull. 354, 1908, pp. 135, 136, 182.

polished face is a dark olive-smoke color. Its texture is even-grained medium, with feldspars to 0.3 inch and black silicate to 0.1 inch. Its constituents, in descending order of abundance, are: Medium olive-greenish potash feldspar (orthoclase), intergrown with soda-lime feldspar (probably albite) in alternating bands (microperthite), the feldspar sections almost all nearly rectangular; black (in thin section green) augite; biotite (black mica); greenish hornblende; rare grains of quartz with sheets of cavities; very little separate soda-lime feldspar (probably albite). Accessory: Magnetite, titanite, apatite. Secondary: Limonite from magnetite and biotite following the banding of feldspars. This is conspicuous in long-exposed specimens. There is no effervescence with muriatic acid test.

The olive tint, as in other green granites, is probably due to the combination of limonite with the originally bluish color of the feldspar. The stone takes a high polish, but some blocks are streaked either from flow structure or from veinlets.

The quarry (the upper and more recent of two openings) is about 50 feet square and 10 feet deep.

The sheets, 1 to 5 feet thick, dip 30° SW. Joints (*a*) strike N. 45° W., vertical, and are spaced 6 to 30 feet. Set (*b*) strikes N. 65° E., vertical or steep southwest, one only on northwest side, slickensided. Minute veins run parallel to joints (*b*), spaced 6 inches to 3 feet and more, and disfigure that part of the rock. An aplite dike, 2 inches wide, strikes east and dips 40° S. Rusty stain on sheet surfaces is not over an inch thick.

There is no plant.

The quarry road to the highway at the foot of the ridge is over one-half mile long. There is a disused lumber-railroad bed from the Boston and Maine Railroad at Lancaster, within a mile of the quarry.

Some steps on the south side of the Lancaster House in Lancaster are of this granite.

DAWSON QUARRY.

The Dawson quarry is in Stark Township, 3 to 4 miles due east of Groveton station, on a north-south ridge about 800 feet above the station. Operators, Cushing & Frizzell, Groveton, N. H.

The granite (specimens D, XXX, 74, a, e), "Stark," is a biotite granite of medium pinkish-gray color (a trifle darker than Concord granite) and of even-grained medium texture, with feldspars under 0.4 inch and micas to 0.2 inch, exceptionally 0.3 inch. Its constituents, in descending order of abundance, are: Pinkish potash feldspar (orthoclase), obscurely intergrown with plagioclase (probably oligoclase-albite) and much kaolinized; medium smoky quartz with cavities in sheets, a few in a set at right angles to the others; pinkish soda-lime feldspar (oligoclase-albite); biotite (black mica), some of it chloritized; and rarely a scale of bleached biotite or muscovite. Accessory: Magnetite, allanite, apatite. Secondary: Kaolin, a white mica, limonite, epidote, chlorite. There is no effervescence with muriatic acid test.

An estimate of the mineral percentages by the Rosiwal method yields these results with a mesh of 0.3 inch and a total linear length of 66.4 inches:

Estimated mineral percentages in Stark granite.

Feldspar	70.14
Quartz	27.15
Mica	2.71
	100.00

This is a constructional granite of dull pinkish color and feeble contrast, which, however, may become stronger as the quarry deepens.

The quarry, opened before 1897, measures about 50 by 30 feet and 8 to 20 feet in depth. The stripping consists of 1 to 3 feet of sand, loam, and small bowlders.

The sheets, from 6 inches to 3 feet thick, are horizontal. One set of vertical joints strikes N. 80° W. and is spaced 20 feet. There are traces of a north-south set. A few discontinuous ones strike N. 50° E. There are fine-grained light-gray and also black segregations, some of the latter with biotite and quartz particles inclosed in whitish lenses.

The plant consists of a hand derrick.

The quarry is operated only in winter, on account of the economy of sledding the stone to Groveton rather than carting it over bad roads.

The product is used for trimmings. Specimens: Trimmings of court-house, Berlin, N. H., and of several buildings in Lancaster, and a monument in the cemetery at Groveton, N. H.

The firm has also opened another quarry in the same stone about a mile north of this one, in Stark. It is near the Grand Trunk Railway and thus has better shipping facilities.

GRAFTON COUNTY.

MASCOMA QUARRY.

The Mascoma quarry is on the top of a knoll 1½ miles north-northeast of Enfield station, in Canaan Township. Operator, Norcross Brothers Company, Worcester, Mass.

The granite (specimens D, XXX, 77, a, b, c), "Mascoma," is a biotite granite gneiss of light buff-gray color speckled with black, and of even-grained, somewhat gneissoid coarse texture, with feldspars to 0.7 inch and mica aggregates to 0.4 inch. Its constituents, in descending order of abundance, are: Very light buff-gray (almost cream-colored) potash feldspar (microcline and orthoclase), slightly kaolinized; light smoky quartz, coarsely granulated, with cavities in sheets and cracks parallel thereto; milk-white soda-lime feldspar (oligoclase), much intergrown with quartz minutely circular in cross section, generally kaolinized and micacized; biotite (black mica), some of it chloritized; and very little muscovite or bleached biotite. Accessory: Magnetite, titanite, apatite, zircon. Secondary: Kaolin, a white mica, chlorite, calcite, rare limonite stain, and probably hematite. It effervesces with muriatic acid test.

This is a constructional granite, in some respects resembling that of Milford, Mass.[a] It takes a fair polish and the polished face shows some magnetite. The contrasts are chiefly between the black mica and the other minerals.

The quarry, opened in 1907, measures about 147 by 70 feet and 5 to 25 feet in depth. The stripping averages about 18 inches.

The sheets, from 6 inches to 3 feet thick and more, are about horizontal, forming short lenses. There are three sets of joints: Set (*a*), striking N. 50° E., dipping 70° N. 40° W., is spaced 2 to 25 feet and forms a heading at the northwest corner; set (*b*), striking N. 80° W., dipping S. 10° W., is spaced 2 to 25 feet; set (*c*), striking N. 65° E., dipping 60° N. 25° W., is spaced 4 to 8 feet and more. Flow structure strikes north. In the center of the quarry is a flowage band with more pinkish feldspars. The rift is reported as horizontal and the grain as vertical, with N. 32° W. course. A pegmatite dike (smoky quartz and feldspar) up to 5 inches thick dips 20° NW. There are also lenses or veins of smoky quartz up to 4 inches thick. Biotitic knots measure up to 6 inches across. There is hardly any rusty stain along the surfaces of lower sheets, and on joint faces it is not over 2 inches thick.

The plant consists of a derrick and hoisting engine.

Transportation is by cartage 2 miles to Enfield station.

The product is used mainly for buildings. Specimens: Tercentennial commemorative monument, Jamestown, Va.; lower stories of Slater Building, Worcester, Mass.; polished base course, Agricultural National Bank, Pittsfield, Mass.; Plain Dealer Building, Cleveland, Ohio; Carnegie Institute, Pittsburg, Pa. In 1909 a contract was being filled for the Royal Bank of Canada at Winnipeg, Manitoba.

POND LEDGE QUARRIES.

The Pond Ledge quarries are on the southeast side of the domelike granite mass known as Briar Hill, about a mile from Haverhill Center and about 3 miles west of Black Mount station (North Haverhill), in Haverhill Township. Briar Hill lies about N. 60° W. of Black Mountain. Operator, Jessman Granite Company, North Haverhill, N. H.

[a] Compare Bull. U. S. Geol. Survey No. 354, 1908, p. 75.

The granite from the southwestern quarry (specimen D, XXX, 75, a), "Pond Ledge gray," is a biotite-muscovite granite of light inclining to medium gray shade, and of even-grained fine texture, but with sparse porphyritic clear feldspars to 0.4 inch and mica under 0.1 inch. Its constituents, in descending order of abundance, are: Clear, colorless potash feldspar (microcline and orthoclase); clear, colorless quartz with cavities and hairlike crystals of rutile, and granulated; milk-white soda-lime feldspar (oligoclase-albite), kaolinized, micacized, and with calcite; biotite (black mica), some of it chloritized; muscovite (white mica). Accessory: Magnetite, titanite, apatite, zircon, allanite, rutile. Secondary: Kaolin, a white mica, calcite, epidote, chlorite. The stone effervesces with the muriatic acid test.

The granite from the northeastern quarry (specimens D, XXX, 75, b, c), "Pond Ledge pink," is a biotite-muscovite granite of light pinkish-gray color and even-grained fine texture, but with sparse porphyritic feldspars to 0.3 inch and micas to 0.1 inch, rarely 0.2 inch. Its constituents are identical with those of the gray (specimen 75, a), but the secondary minerals include some hematite, which produces the pinkish tint.

This stone takes a good polish. It is said to lose some of its pinkish tint on continued exposure.

These "quarries" merely utilize the talus of Briar Hill; that is, material already quarried by glacier, frost, etc. The blocks are attacked at two points about 1,000 feet apart.

The structure above the talus is not clear. The sheets on top of the hill are said to be horizontal and to range from 6 inches to 10 feet in thickness. On the side above the talus some steep joints or sheets strike nearly with the face of the cliff and are spaced 20 feet and more. There are also gently northwestward-dipping planes, possibly headings. The two granites are reported as merging into each other, the rift as dipping gently northwest, and the "head grain" as forming an angle of 75° to 80° to it. Knots are 2 inches across. Rusty stain is an inch thick on sheets, rarely 6 to 8 inches.

The plant comprises two derricks, an air compressor (capacity 14 cubic feet of air per minute), two air hand tools, a traveling overhead crane, and a 10-horsepower gasoline engine.

Transportation is by cartage 3 miles to rail.

The product is used for monuments at Bath, Lisbon, Haverhill, and Haverhill Center cemeteries.

LEBANON QUARRY.

The Lebanon quarry is at the east foot of Quarry Hill, on the west side of and close to the Hanover-Lebanon road, 1¼ miles north of Lebanon village, in Lebanon Township. (See map of Hanover quadrangle, U. S. Geol. Survey.) There are some now disused quarries of the same granite higher up on Quarry Hill. Operator, Pigeon Hill Granite Company, Rockport, Mass.

The granite (specimens D, XXX, 76, a, b), "Lebanon pink," is an epidotic biotite granite gneiss of light, faintly pinkish and greenish gray color, speckled with greenish black, and of gneissoid coarse texture, with feldspars to 0.7 inch and mica aggregates to 0.4 inch. Its constituents, in descending order of abundance, are: Light-pinkish potash feldspar (microcline and orthoclase, some minutely intergrown with plagioclase), more or less kaolinized; clear, colorless quartz, with cavities and few hairlike crystals of rutile, finely granulated; a little greenish soda-lime feldspar (oligoclase-albite to albite), much kaolinized and epidotized; biotite (black mica), usually associated with epidote and some of it chloritized; and a little muscovite (white mica). Accessory: Magnetite, pyrite, titanite. Secondary: Epidote kaolin, calcite, a white mica, chlorite. Epidote is fifth in order of abundance. In places the feldspars are surrounded by crushed feldspars and epidote. The stone effervesces with muriatic acid test.[a]

This is a constructional granite of mixed greenish and pinkish tint and gneissoid texture, resembling in some respects the granite of Milford, Mass., and also that of Canaan, N. H.[b] The polish is poor owing to large mica aggregates. The polished face shows magnetite and pyrite.

The present quarry, hardly fully opened in 1909, is on a glaciated ledge stripped in places of 5 to 10 feet of clay. The opening measures 150 by 50 feet and up to 10 feet in depth.

The sheets, 5 to 10 feet thick, are about horizontal. There are four sets of joints. Set (*a*), striking N. 43° W., vertical or dipping steep northeast, also 35° NE., is spaced 10 to 20 feet; set (*b*), striking N. 25° E., dipping 70° S. 65° E.; set (*c*), striking N. 15° W., dipping 55° S. 75° W., is spaced 10 feet and more; set (*d*), striking N. 80° E., dipping 40° N. 10° W., faced with secondary muscovite, is spaced 9 feet and more. The rift is probably horizontal. Dikes of light-pinkish aplite up to 3½ inches thick range from the horizontal to a dip of 30° W. Light and dark segregations are up to 4 inches across. Rusty stain on sheet surfaces is slight and not over 2 inches thick.

The plant comprises one derrick and a hoisting engine at the quarry and another derrick and small hoisting engine and air compressor (capacity 300 cubic feet of air per minute) at the cutting shed.

Transportation is by cartage 1¼ miles to rail at Lebanon.

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[a] A full microscopic description of this granite was given by J. P. Iddings in Bull. U. S. Geol. Survey No. 150, 1898, p. 353. He regarded the epidote as mostly primary. (See in this connection Butler, B. S., Pyrogenetic epidote: Am. Jour. Sci., 4th ser., vol. 28, July, 1909, pp. 27-32.)

This gneissoid granite belongs in an area designated as protogene in Prof. C. H. Hitchcock's Geology of the Hanover, N. H., quadrangle. See Rept. State Geologist Vermont, vol 6, 1907-8, Pl. XXV (a) and pp. 165, 166.

[b] See Bull. U. S. Geol. Survey No. 354, 1908, p. 75, also this bulletin, p. 98.

The product is used for buildings. Specimens of the same granite but largely from now disused openings are the following: India Building, Boston; two stories (polished) of the New York Mutual Life Insurance Building on Chestnut street, Philadelphia; two stories of the Borden Building on Hudson street, New York. The stone has also been used to some extent in the chapel, hospital, and Butterfield Memorial buildings of Dartmouth College, at Hanover, N. H.

HILLSBORO COUNTY.

O'ROURKE QUARRY.

The O'Rourke quarry is at the east end of Brookline village, in Brookline Township. (See map of Groton quadrangle, U. S. Geol. Survey.) Operator, O'Rourke & Magner Granite Company, Brookline, N. H., also 78 North street, Salem, Mass.

The granite (specimen D, XXX, 87 a), "Brookline," is a quartz monzonite of medium buff-gray color and of even-grained fine texture, with feldspars and micas under 0.2 inch. Its constituents, in descending order of abundance, are: Light smoky quartz with cavities; cream-colored soda-lime feldspar (oligoclase), kaolinized and micacized; clear to translucent whitish potash feldspar (microcline and orthoclase), intergrown with quartz, circular in cross section; biotite (black mica), some of it chloritized; and a little muscovite or bleached biotite. Accessory: Magnetite, apatite, zircon. Secondary: Kaolin, a white mica, calcite, chlorite. There is no effervesence with muriatic acid test.

This is a fine-grained monumental granite closely related to that of Milford, in the same county.[a] It cuts light.

The quarry, opened in 1909 but adjacent to an opening made in 1891, is on a bare ledge measuring 200 feet in a N. 20° E. direction by 100 feet across.

The sheets, 1 to 8 feet thick, dip mostly east at low angles. There are two sets of joints. Set (*a*), striking N. 20° E., vertical, spaced 6 to 12 feet, forms a small heading on the west side; set (*b*), striking N. 80° W., vertical, is spaced 25 feet and more. The rift is reported as horizontal and the grain as vertical. Inclusions of gneiss up to 6 by 3 feet occur on the southwest side. (See p. 347.) Rusty stain is 2 inches thick on surface sheets, but there is very little on the lower ones.

The plant consists of a 15 to 20 ton horse derrick and a hand derrick.

Transportation is by cartage three-fourths of a mile to the railroad.

The product is used for monuments and trimmings. Specimens from the older opening: Simon Cottan and Philip Sheridan monuments in St. Mary's cemetery, Salem, Mass.

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[a] See Bull. U. S. Geol. Survey No. 354, 1908, pp. 159, 160.

FESSENDEN QUARRY.

The Fessenden quarry is one-eighth of a mile west of South Brookline station, in Brookline Township. (See map of Groton quadrangle, U. S. Geol. Survey.) Operator, O. D. Fessenden, South Brookline, N. H.

The granite (specimens D, XXX, 88, a, b), "Brookline," is a quartz monzonite of medium, faintly pinkish gray color, and of even-grained fine texture, with feldspars to 0.15 inch and micas to 0.1 inch. Its constituents, in descending order of abundance, are: Very light smoky quartz with cavities and hairlike crystals of rutile; milk-white soda-lime feldspar (oligoclase), kaolinized and micacized; slightly pinkish potash feldspar (microcline and presumably orthoclase); biotite (black mica), some of it chloritized; and a little muscovite or bleached biotite. Accessory: Magnetite, apatite, zircon, allanite. Secondary: Kaolin, white micas (one in veinlets), hematite and limonite stain, chlorite, calcite. There is very slight effervescence with the muriatic acid test.

An estimate of the mineral percentages, made by applying the Rosiwal method to a camera lucida drawing of a thin section enlarged 40 diameters, yields these results with a mesh of 2 inches and a total linear length of 48 inches:

Estimated mineral percentages in Brookline quartz monzonite from Fessenden quarry.

Soda-lime feldspar (oligoclase)	38.79	61.71
Potash feldspar (microcline and orthoclase)	22.92	
Quartz		32.20
Black mica (biotite)	5.08	5.24
White mica (muscovite) or bleached biotite	.16	
Magnetite		.85
		100.00

The average diameter of the particles calculated from the same measurements proves to be 0.0097 inch.

This is a fine-grained monumental granite, related to that of Milford, in the same county.[a] Its color is warmer than that of the rock from the O'Rourke quarry (p. 361), but the granites are the same. It takes a high polish and like other quartz monzonites cuts light.

The quarry, opened in 1909, is about 80 by 50 feet and up to 8 feet deep. The stripping consists of 2 to 6 feet of loam.

The sheets, 2 to 3 feet thick, range from the horizontal to a gentle easterly dip. There are two sets of joints. Set (*a*) strikes N. 30° E., vertical, one only in center; set (*b*), striking N. 75° W., vertical or steep, is spaced 10 to 20 feet. The rift is reported as horizontal and the grain as vertical, with N. 20° E. course. There are inclusions

[a] See Bull. U. S. Geol. Survey No. 354, 1908, pp. 159, 160.

of coarse gneiss and granite to 21 inches in diameter. (See p. 347.) Rusty stain on top sheets is not over 2 inches thick.

Transportation is by cartage one-eighth of a mile to rail.

The product is used for monuments and has been shipped to Milford, Pepperell, and Claremont, N. H., to Quincy, Mass., and to Ohio and Pennsylvania.

KENNARD LEDGE QUARRY.

The Kennard Ledge quarry is 1½ miles about northeast from the city hall in Manchester. Operator, Evariste Dionne, 368 Lake avenue, Manchester, N. H.

The granite (specimen D, XXX, 82, a) is a biotite granite of medium buff-gray color and of even-grained medium texture, with feldspars up to 0.3 inch, rarely 0.4 inch, and micas under 0.2 inch. The mica scales lie parallel to the rift. Its constituents, in descending order of abundance, are: Greenish-gray potash feldspar (microcline), slightly kaolinized; medium smoky quartz with cavities in sheets; buff-gray soda-lime feldspar (oligoclase-andesine), some of it much kaolinized and micacized; biotite (black mica), some of it chloritized; and a little muscovite or bleached biotite. Accessory: Pyrite, magnetite, allanite, apatite, zircon. Secondary: Kaolin, a white mica, chlorite, calcite. There is no effervescence with the muriatic acid test.

The quarry, opened about 1879, measures about 300 feet from east to west by 150 feet across and 60 feet in depth.

The sheets, 6 inches to 9 feet thick, dip low north on the north side and low south on the south side. There is but one set of joints. This strikes N. 17° W., vertical, is spaced 14 to 22 feet, and forms a 20-foot wide heading on the south side. The rift is reported as horizontal and the grain as vertical with east-west course, both being well marked. The north wall of the quarry is gneiss with thick dikes and lenses of pegmatite. The gneiss foliation strikes N. 80° E. and dips 75° N. 20° W. The south wall is of similar gneiss. The granite thus appears to be a dike 150 feet wide with a north-south strike, crossing a gneiss with a nearly east-west foliation. Rusty stain is up to 8 inches thick on sheet surfaces.

The plant comprises one hand derrick.

Transportation is by cartage to the city.

The product is used for foundations, trimmings, and curbing, for which its marked rift and grain well adapt it.

BODWELL QUARRY.

The Bodwell quarry is about 2½ miles east-northeast of the city hall in Manchester. Operator, T. Paradis, 210 Manchester street, Manchester, N. H.

The granite (specimen D, XXX, 83, a) is a biotite granite of light inclining to medium gray shade and of even-grained medium texture with feldspars to 0.3 inch (exceptionally 0.5 or 0.7). Its constituents, in descending order of abundance, are: Clear, colorless to translucent potash feldspar (microcline), intergrown with quartz, circular in cross section, slightly kaolinized and micacized; light smoky quartz with cavities in sheets; milk-white soda-lime feldspar (oligoclase-andesine), some of it much kaolinized and micacized; biotite (black mica), some of it chloritized. Accessory: Magnetite, allanite. Secondary: Kaolin, white micas, calcite, chlorite. Much effervescence with the muriatic acid test.

The quarry, opened about 1879, measures about 350 feet in a N. 70° E. direction by 65 feet across and 20 to 40 feet in depth.

The sheets, 2 to 6 feet thick, dip 5° S. There is one set of joints only, striking N. 35° W., vertical, spaced irregularly. The rift is reported as horizontal and the grain as vertical with N. 57° E. course. The quarry is walled on its longer sides by banded quartz-mica diorite gneiss of varying texture and pegmatite lenses. The gneiss foliation strikes N. 45° E. There are tongues and inclusions of this gneiss in the granite. Rusty stain is 2 to 3 inches thick on sheet surfaces.

The plant consists of a derrick and hoisting engine, three hand derricks, a steam rock drill, and a steam pump.

Transportation is by cartage.

The product is used for foundations and curbing.

STEVENS QUARRY.

The Stevens quarry is near West Hollis street, in Nashua, 2¼ miles west-southwest of the confluence of Nashua and Merrimac rivers. (See map of Manchester quadrangle, U. S. Geol. Survey.) Operator, Nashua Granite Company, 254 Main street, Nashua, N. H.

The granite (specimen D, XXX, 86, a) is a muscovite-biotite granite gneiss of light-gray shade and of gneissic medium texture, with feldspars under 0.4 inch (rarely 0.7 inch) and micas under 0.2 inch. The rift is at right angles to the foliation. Its constituents, in descending order of abundance, are: Milky potash feldspar (microcline, some of it kaolinized, and orthoclase); light smoky quartz, with hairlike crystals of rutile and granulated (particles 0.05 to 0.25 millimeter across); milk-white soda-lime feldspar (albite to oligoclase-albite), much kaolinized and somewhat micacized; muscovite (white mica) in plates and stringers, which with the granulated quartz surround the larger feldspars; biotite (black mica), a little of it chloritized. Accessory: Garnet, apatite, rutile. Secondary: Kaolin, white micas, chlorite. There is no effervescence with the muriatic acid test.

The quarry, opened about 1840, measures about 175 feet in a northeast direction by 125 feet across and from 10 to 20 feet in depth. The stripping is up to 5 feet thick.

The sheets, from 6 inches to 6 feet thick, dip 10° SE. There are two sets of joints. Set (*a*), striking northeast, vertical, spaced 5 to 20 feet, forms a heading on the northwest wall, one 15 feet from the southeast wall, and a discontinuous one on the northeast wall. Set (*b*), striking N. 60° W., vertical, is less abundant and at irregular intervals. The foliation strikes N. 67° E., dips 90°, and has micaceous faces. The rift is horizontal and the grain parallel to the foliation and the hardway is vertical with northwest strike. A pegmatite dike up to a foot thick, on the northeast side, strikes northeast. A pegmatite lens, 30 by 3 to 4 feet, has the same strike.

The plant consists of two derricks and two hoisting engines, three hand derricks, and a steam pump.

Transportation is by siding from the Boston and Maine Railroad.

The product is used for trimmings and curbing, for which its foliation and marked rift well adapt it, and also for foundations.

MERRIMAC COUNTY.

BAILEY QUARRY.

The Bailey quarry is in Allenstown, 2 miles about north-northeast of Suncook station. Operator, Charles A. Bailey, Suncook, N. H.

The granite (specimens D, XXX, 81, a, b), "Allenstown," is a muscovite-biotite granite of light-gray shade and of even-grained medium texture, with feldspars to 0.3 inch and mica to 0.2 inch, rarely 0.3 inch. In places, owing to flow structure, it is more micaceous than in others. Its constituents, in descending order of abundance, are: Clear, colorless potash feldspar (microcline and orthoclase (?); very light smoky quartz with hairlike crystals of rutile and cavities in sheets; milk-white soda-lime feldspar (oligoclase-albite), kaolinized and micacized; muscovite (white mica); biotite (black mica). Accessory: Apatite, rutile. Secondary: Kaolin, a white mica, calcite. It effervesces slightly with the muriatic acid test.

The quarry, opened about 1874, is on the northwest side of a low granite dome and measures about 500 feet in a northeast direction by 250 feet across and from 20 to 60 feet in depth; the stripping consists of sand averaging 1 foot thick, but the rock is mostly bare.

The sheets, 6 inches to 6 feet thick, dip gently northeast and northwest. There are two sets of joints: Set (*a*), striking N. 60° E., vertical, is rare; set (*b*), striking N. 60° W., vertical, forms a heading 40 feet wide within 200 feet of the northeast end of the quarry. The rift is reported as horizontal and the grain as vertical, with

N. 60° E. course. A hornblende diabase dike 3 to 4 feet wide crosses the quarry lengthwise within 75 feet of the working face, with a N. 60° E. strike and vertical or steep dip. The granite is darker for 14 feet on one side of the dike and 2 feet on the other. (See p. 348.) Three pegmatite dikes, from 14 inches to 5 feet thick, strike about N. 60° W. and dip 45° N. 30° E. to 90°. Some of the granite near the heading of set (*b*) is porphyritic and has large micas. A flow structure appears also in places. Biotitic knots measure to 5 inches.

The plant comprises six derricks at the quarry and two at the cutting shed one-half mile toward Suncook station, three hoisting engines, a small locomotive, an air compressor at the quarry (capacity 338 cubic feet of air per minute), one at the cutting shed on Elm street, Manchester (capacity about 100 cubic feet of air per minute), three large air rock drills, nine air-plug drills, six air hand tools at the sheds, and a stone crusher with meshes of one-fourth, one-half, 1½, and 2½ inches and a capacity of 125 tons per day.

Transportation is by private siding a mile long to the Suncook Valley branch of the Boston and Maine Railroad.

The product is used partly for trimmings but mainly for foundations, curbing, paving, and crushed stone for concrete. Its market is mostly within the State. Specimens: Weston observatory, foundation and trimmings of Coolidge mill and New Manchester mill of the Amoskeag Manufacturing Company, Manchester, N. H.

SHIRLEY QUARRY.

The Shirley quarry is near Merrimac River in Hooksett, 6 miles north of Amoskeag, Manchester. Operator, George N. Shirley, 255 Front street, Manchester, N. H.

The granite (specimen D, XXX, 80, a) is a muscovite-biotite granite of very light gray shade and medium texture, with feldspars and micas to 0.3 inch, the white mica being in rhombic crystals. Its constituents, in descending order of abundance, are: Milky potash feldspar (microcline), slightly kaolinized; clear, colorless quartz with cavities; milk-white soda-lime feldspar (oligoclase-albite), much kaolinized and somewhat micacized; muscovite (white mica), mostly in rhombic crystals; biotite (black mica). Accessory: Magnetite, apatite. Secondary: Kaolin, a white mica, calcite. The stone effervesces with the muriatic-acid test.

The quarry, opened in 1891, is small and was not visited by the writer.

The plant comprises a steam derrick and hoisting engine, two horse derricks at the stone yard at Amoskeag, a small air compressor, a large steam drill, two air-plug drills, and a 14-horsepower steam tug.

The stone is brought down Merrimac River 6 miles in a steam tug to the cutting yard at Amoskeag and carted to its destination.

The product is used for curbing, steps, underpinning, and trimmings. Specimens: Trimmings on Amoskeag school and on Manchester Street Railway car barn.

STRAFFORD COUNTY.

LANGMAID QUARRY.

The Langmaid quarry is in Rochester Township, 5 miles northwest of Dover. Operator, Linville F. Langmaid, 26 South Pine street, Dover, N. H.

The granite (specimen D, XXX, 84, a) is a biotite granite of very light gray shade, with close dark specks, and of even-grained medium texture, with feldspars to 0.3 inch and micas to 0.2 inch. Its constituents, in descending order of abundance, are: Clear to translucent potash feldspar (microcline and orthoclase); medium smoky quartz with cavities in sheets and hairlike crystals of rutile; milk-white soda-lime feldspar (oligoclase-albite), most of it kaolinized and micacized; biotite (black mica), some of it chloritized; and a little muscovite or bleached biotite. Accessory: Magnetite, rutile. Secondary: Kaolin, a white mica, chlorite, calcite. It effervesces slightly with the muriatic acid test.

This is a constructional granite with marked contrast of shade between its smoky quartz and milk-white feldspar.

The quarry, opened before 1879, measures about 300 by 90 feet and from 12 to 15 feet deep. The stripping consists of 2 to 10 feet of loam.

The sheets, 1 to 8 feet thick, are horizontal. There are three sets of joints—a longitudinal, a transverse, and a diagonal set—spaced generally 10 to 20 feet. The rift is reported as horizontal and the grain as vertical with north-south course. There are several pegmatite dikes a few inches thick and one at the edge more than a foot thick. Rusty stain is usually 1 to 3 inches but in places 8 inches thick on sheet surfaces.

The plant comprises one horse and one hand derrick.

Transportation is by cartage 5 miles to Dover or Rochester.

The product is used for bases, trimmings, and faces. Specimen: Some of the trimmings of the court-house at Dover, N. H.

The quarry has been idle for over a year. The thickness of the sheets and the prospective improvement in the quality of the stone are favorable, but its distance from rail is against it.

SULLIVAN COUNTY.

SPECTACLE POND QUARRY.

The Spectacle Pond quarry is at the southeast corner of Sunapee Township, about one-fourth mile south of Spectacle Pond and one-fourth mile southwest of Edgemont (formerly Mount Sunapee), station. (See map of Sunapee quadrangle, U. S. Geol. Survey.) Operator, Ola Anderson, Concord, N. H.

The granite (specimen D, XXX, 78, a), "Spectacle Pond," is a biotite-muscovite granite of light buff-gray shade and of even-grained fine texture, with feldspars to 0.2 inch, rarely 0.25 inch, and micas under 0.1 inch. Its constituents, in descending order of abundance, are: Clear, colorless potash feldspar (microcline and orthoclase); light smoky quartz with hairlike crystals of rutile and with cavities in sheets and cracks parallel thereto; cream-colored soda-lime feldspar (oligoclase-albite), more or less kaolinized and micacized; biotite (black mica); muscovite (white mica). Accessory: Garnet, apatite, rutile. Secondary: Kaolin, a white mica. There is no effervescence with the muriatic acid test.

This is a fine-grained monumental granite. Its shade may be less buff and even bluish farther below the surface.

The quarry, opened in 1909, is 75 feet square and 3 to 8 feet deep. There is little or no stripping.

The sheets, 1 to 5 feet thick, dip 15° about northeast. There are three sets of joints. Set (*a*), striking N. 10° E., dipping 80° W., forms a heading on the east side and is spaced 5 to 10 feet; set (*b*), striking northeast, dipping 65° NW., forms a heading at the southwest corner and is spaced 10 to 25 feet; set (*c*), striking N. 30° E., dipping 70° N. 60° W., forms a heading 10 feet wide through the middle of the quarry. The rift is reported as horizontal and the grain as vertical with nearly east-west course. A quartz vein up to 5 inches thick crosses the middle of the quarry, with N. 70° E. strike and dip of 60° N. 20° W. Rusty stain is up to 4 inches thick on sheet surfaces.

The plant comprises one derrick and hoisting engine, a horse derrick at the station, an air compressor (capacity 175 cubic feet of air per minute), a steam rock drill, and two air-plug drills.

Transportation is by cartage one-fourth mile to rail.

The product of the upper sheets is now being sold for curbing, but that of the lower sheets, when reached, will be used for monuments.

PERRY SUNAPEE QUARRY.

The Perry Sunapee quarry is on the top of a 200-foot knoll one-half mile west of Burkehaven, on Lake Sunapee, and three-fourths of a mile south-southeast of Sunapee village, in Sunapee Township. (See map of Sunapee quadrangle, U. S. Geol. Survey.) Operators, W. H. Perry & Co., Concord, N. H.

Specimens from this quarry (D, XXVIII, 47, a, b), "light Sunapee," were described in Bulletin 354, page 187, but the quarry had not then been visited by the writer. An examination of specimens (D, XXX, 79, a, aa) collected by the writer does not yield any important difference. It is a fine-grained, light, slightly bluish gray monumental granite with biotite and muscovite in about equal amounts, and the second feldspar is oligoclase.

The quarry, opened in 1869, measures about 150 by 100 feet and from 15 to 30 feet in depth.

The sheets, 6 inches to 3 feet thick, are undulating. There are no joints. The rift is probably horizontal and the grain vertical with N. 80° W. course. A pegmatite dike up to 30 inches thick, striking N. 30° E. and vertical or steep, forms part of the east wall. A 3-foot dike striking about east forms the north wall. Other pegmatite dikes up to 6 inches thick, striking N. 50°–70° E., recur at intervals of 5 to 20 feet. A vertical porphyritic granite mass, also striking N. 30° E., forms the west wall. Two large inclusions of quartz-mica diorite gneiss (described more fully on p. 347) occur near the south end of the east wall, apparently in a coarser granite. Biotitic segregations measure to 4 inches across.

The plant comprises a hand and a steam derrick, a hoisting engine, an air compressor, two steam rock drills, and several air-plug drills.

Transportation is by cartage more than 3 miles to Sunapee station, on the Claremont branch of the Boston and Maine Railroad.

The product is used for monuments, which are finished at the firm's cutting shed at Concord. The quarry is operated only occasionally.

CLASSIFICATION OF NEW HAMPSHIRE GRANITES.

In the following table all the granites described are commercially classified, as *constructional, monumental, inscriptional, polish, curbing,* and *trimming* granites. Those previously described from this State in Bulletin 354 have been added in their places, so that the table affords a survey of all the granites of the State of known commercial value. The scientific names of the granites are also given and references to the detailed descriptions.

Classification of New Hampshire granites.

CONSTRUCTIONAL.

Locality.	Trade name.	General color and shade.	Texture.	Petrographic name.	Reference.
Concord (various quarries)	Concord	Medium bluish gray	Fine medium, somewhat porphyritic.	Muscovite-biotite granite	Bull. 354, pp. 146–156.
Troy (Troy quarry)	Troy white	Light inclining to medium bluish gray.	Fine	do	Bull. 430, pp. 353–355.
Fitzwilliam (Webb quarry)	FitzwilliamWebb	Light, very bluish gray	do	do	Bull. 430, pp. 348–349.
Fitzwilliam (Holman quarry)	Fitzwilliam	Light bluish gray	Medium inclining to fine	do	Bull. 430, p. 352.
Fitzwilliam (Silver White quarry)	Silver White	do	Very fine (average diameter, 0.00668 inch).	Biotite-muscovite granite	Bull. 430, pp. 349–350.
Fitzwilliam (Snow Flake quarry)	Snow Flake	Light inclining to medium gray	Porphyritic with fine matrix	do	Bull. 430, p. 351.
Marlboro (Marlboro quarry)	Marlboro	Light inclining to medium, very bluish gray.	Fine	do	Bull. 430, pp. 352–353.
Stark (Dawson quarry)	Stark	Medium pinkish gray	Medium	Biotite granite	Bull. 430, pp. 356–357.
Canaan (Mascoma quarry)	Mascoma	Light buff-gray	Gneissoid, coarse	Biotite granite gneiss	Bull. 430, pp. 357–358.
Lebanon (Lebanon quarry)	Lebanon pink	Light, faintly pinkish-greenish gray.	do	Epidotic biotite granite gneiss	Bull. 430, pp. 359–361.
Redstone (Redstone quarry)	Redstone red	Light pink mottled with dark gray.	Coarse	Biotite granite	Bull. 354, p. 179.
Madison (Fletcher & Lahey quarry)	Madison	Light pinkish gray mottled with dark purplish gray.	do	do	Bull. 354, p. 185.
North Conway (White Mountain quarry).	North Conway	Medium pinkish buff-gray	do	do	Bull. 354, p. 184.
Kilkenny (Kilkenny quarry)	Kilkenny	Dark olive-green	Medium	Augite-biotite granite	Bull. 430, pp. 355–356.
Milford (Carlton quarry)	Milford building	Medium pinkish gray	Porphyritic	Quartz monzonite, probably.	Bull. 354, p. 175.
Milford (Lovejoy quarry)	do	Light gray	Fine inclining to medium	Quartz monzonite	Bull. 354, p. 160.
Milford (Kittredge and Pease quarries).	do	Light gray with very slight bluish tinge.	do	do	Bull. 354, pp. 161, 163.
Milford (Pease quarry)	Milford building, pink.	Light buff-gray, some slightly pinkish.	do	do	Bull. 354, p. 163.

MONUMENTAL.

Locality.	Trade name.	General color and shade.	Texture.	Petrographic name.	Reference.
Fitzwilliam (Silver White quarry).	Silver White	Light bluish gray	Very fine (average diameter, 0.0068 inch).	Biotite-muscovite granite	Bull. 430, pp. 349–350.
Troy (Troy quarry)	Troy white	Light inclining to medium bluish gray.	Fine	Muscovite-biotite granite	Bull. 430, pp. 353–355.
Haverhill (Pond Ledge quarry)	Pond Ledge gray	Light inclining to medium gray	Fine, but with sparse porphyritic feldspars.	Biotite-muscovite granite	Bull. 430, pp. 358–359.
Do.	Pond Ledge pink	Light pinkish gray	do	do	Bull. 430, pp. 358–359.
Sunapee (Spectacle Pond quarry)	Spectacle Pond	Light buff-gray	Fine	do	Bull. 430, pp. 367–368.

Sunapee (Perry quarry)	Light Sunapee	Light slightly bluish gray	do	With biotite and muscovite in about equal amounts.	Bull. 430, pp. 368–369.
Brookline (O'Rourke quarry)	Brookline	Medium buff-gray	do	Quartz monzonite	Bull. 430, p. 361.
South Brookline (Fessenden quarry).	do	Medium, faintly pinkish gray	Fine (average diameter, 0.0097 inch).	do	Bull. 430, pp. 362–363.
Milford (Young quarry)	Dark blue New Westerly.	Dark gray (smoke color)	Fine (average diameter, 0.0084 inch).	do	Bull. 354, p. 170.
Milford (New Westerly quarry)	New Westerly blue	Medium, slightly bluish gray	Fine (average diameter, 0.009 inch).	do	Bull. 354, p. 173.
Milford (Tonella old quarry)	Milford	Light gray	Fine (average diameter, 0.011 inch).	do	Bull. 354, p. 164.
Milford (Comolli and Paradis quarries).	do	Light inclining to medium bluish gray.	Very fine	do	Bull. 354, pp. 167, 168.
Milford (Souhegan quarry)	do	Dark gray with very slight pinkish tinge.	Fine	do	Bull. 354, p. 168.
Milford (Bishop quarry)	do	Light gray, faintly cream colored.	do	do	Bull. 354, p. 176.
Auburn (Perry quarry)	Deep pink Auburn	Medium pink-buff	do	do	Bull. 354, p. 186.

INSCRIPTIONAL.

Sunapee	Black pearl	Very dark bluish gray	Fine to medium	Quartz diorite	Bull. 354, p. 187.
Milford (Young quarry)	Dark blue New Westerly.	Dark gray (smoke color)	Fine (average diameter, 0.0084 inch).	Quartz monzonite	Bull. 354, p. 170.
Milford (Souhegan quarry)	Milford	Dark gray with very slight pinkish tinge.	Fine	do	Bull. 354, p. 168.

POLISH.

Madison (Fletcher & Lahey quarry).	Madison	Light pinkish gray mottled with dark purplish gray.	Coarse	Biotite granite	Bull. 354, p. 185.
Redstone (Redstone quarry)	Redstone red	Light pink mottled with dark gray.	do	do	Bull. 354, p. 179.
Do	Redstone green	Dark yellow greenish gray	do	Biotite-hornblende granite	Bull. 354, p. 182.

CURBING AND TRIMMING.

Rochester (Langmaid quarry)	Rochester	Very light gray	Medium	Biotite granite	Bull. 430, p. 367.
Manchester (Kennard Ledge quarry).	Kennard ledge	Medium buff-gray	do	do	Bull. 430, p. 363.
Manchester (Bodwell quarry)	Bodwell quarry	Light inclining to medium gray	do	do	Bull. 430, pp 363–364.
Nashua (Stevens quarry)	Nashua	Light gray	Gneissic; medium	Muscovite-biotite granite gneiss.	Bull. 430, pp. 364–365.
Allenstown (Bailey quarry)	Allenstown	do	Medium	Muscovite-biotite granite	Bull. 430, pp. 365–366.
Hooksett (Shirley quarry)	Hooksett	do	do	do	Bull. 430, pp. 366–367.

CONCLUSION.

It will be noticed that the commercial granites of New Hampshire cover a wide petrographic range, including not only a variety of ordinary granites but also quartz monzonite, biotite-hornblende granite, augite-biotite granite, quartz diorite, and gneisses of various sorts.

Economically they consist mainly of the constructional granites of Concord, Fitzwilliam, Marlboro, Lebanon, Canaan, and Redstone and the monumental granites of Fitzwilliam, Troy, Milford, and Brookline.

While the most notable structure of New Hampshire granite is and probably will for many years continue to be the Library of Congress, there are many widely scattered unpretentious but elegant and beautiful monuments of New Hampshire granite, of which the fragmentary lists appended to the quarry descriptions afford evidence.

OOLITIC LIMESTONE AT BOWLING GREEN AND OTHER PLACES IN KENTUCKY.

By JAMES H. GARDNER.

OCCURRENCE AND DISTRIBUTION.

In recent years there has been a steadily increasing demand for oolitic limestone as a building material, which has brought about a notable development of this kind of stone where it is suitably located relative to transportation facilities. The market has been extended over practically the whole of the eastern United States, the supply coming chiefly from the Mississippi Valley. The region producing the greater amount of oolitic limestone is that of Lawrence County and adjacent localities in Indiana, where the familiar Bedford oolitic limestone is extensively quarried. Closely following this Indiana stone in order of importance is the equally celebrated stone from Warren County, Ky., generally known on the market as "Bowling Green oolite."

The stone from the two regions mentioned is similar in appearance and general character and occurs at about the same horizon in the Mississippian series. The "Bedford" limestone of the Indiana Geological Survey, in which the oolitic stone is the most prominent part, is the same as the Spergen limestone of the Meramec group, in which occur most of the Kentucky oolitic limestones, though some beds of western Kentucky are higher in the stratigraphic series and are known to belong to the Fredonia limestone member of the Ste. Genevieve limestone.[a]

Oolitic limestone is exposed at various places throughout a wide area extending from southern Indiana and Illinois across Kentucky into Tennessee and westward into Missouri. It is probable that the most widely extended beds of oolitic limestone are those of the Spergen limestone, which is included in the St. Louis limestone of many authors. Strictly speaking, the St. Louis limestone, as originally described by G. Engelman in 1847 [b] and later limited by B. F. Shumard,[c] includes those limestones above the main oolitic beds. The

[a] Ulrich, E. O., and Smith, W. S. Tangier, Prof. Paper U. S. Geol. Survey No. 36, 1905, p. 40.
[b] Am. Jour. Sci., 2d ser., vol. 3, pp. 119-120.
[c] Geol. Survey Missouri, First and Second Ann. Repts., pt. 2, 1855, pp. 139, 170, and 181.

name Spergen limestone was proposed by Ulrich and Smith[a] for the limestone beds that had previously been called "Bedford" limestone and that lay below the St. Louis limestone (from which they are distinguished by their more or less oolitic character), because the name "Bedford" in a geologic sense conflicted with the better-established term Bedford shale, of the Carboniferous of Ohio.

In Kentucky east of the Cincinnati arch there is a wide area showing exposures of a formation named by M. R. Campbell the Newman limestone.[b] This limestone occupies a position in the stratigraphic column similar to that of the limestones on the opposite side of the arch which were known formerly as the "St. Louis group," that name, however, having been replaced by Meramec group, including both the St. Louis and the Spergen limestone. The Newman limestone has not been subdivided, but the oolitic limestone of Rockcastle and Pulaski counties, which occurs in this formation, will very probably prove to be closely related to the Spergen in age.

The light-gray permanent color of oolitic limestone, its massive and uniform character, and the ease with which it may be dressed, together with its resistance to weathering and pressure, place it first among all American limestones as a building material and second to none for carved and ornamental designs. The beds of the Spergen, the Ste. Genevieve, and the Newman are apparently very persistent and offer fields for commercial development in numerous localities in Kentucky.

BOWLING GREEN STONE.

The oolitic limestone in the vicinity of Bowling Green is in the form of a massive, homogeneous stratum 22 feet thick, overlain by a varying thickness of hard bluish limestone. This oolitic member has an extensive line of outcrop and has been traced westward to the vicinity of Russellville and Elkton and northward across Barren River. The bed is apparently very uniform both in thickness and in character over this area.

The massiveness of the Bowling Green bed is one of the factors that determine its value. Blocks of large dimension can be cut from the quarry face either horizontally or vertically, with no appreciable difference in the appearance or strength of the stone. The quarried blocks average about 4 by 5 by 8 feet, with the greater dimension horizontal. Vertical jointing is slightly developed, but the interval between joint planes is greater than the thickness of the bed. In the construction of buildings the stone may be placed in any position as regards its bedding, with practically no difference in results. The individuality of grains composing the stone and their similarity in composition and size, together with the great uniformity of conditions

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[a] Ulrich, E. O., and Smith, W. S. Tangier, Prof. Paper U. S. Geol. Survey No. 36, 1905, p. 30.
[b] Bull. U. S. Geol. Survey No. 111, 1893, pp. 28 and 38.

under which the material was deposited, have resulted in a massive stratum without intermediate bedding planes. The stone is a true oolite, the particles being rounded in shape like the roe of fish, about one-fiftieth of an inch in diameter, and firmly cemented by clear calcite. There is usually intermingled with the grains a small and sometimes considerable percentage of finely comminuted particles of fossil Crinoidea and Bryozoa. The stone when it comes fresh from the quarry is buff-gray, but on exposure to the sun and air soon bleaches to a very light gray. This bleaching is due chiefly to evaporation of a small amount of light, volatile petroleum contained in the stone. This oil is very noticeable by scent in the fresh blocks and in the entire working face of the quarry. For a distance of about 25 feet from the outcrop the stone as shown in the quarries is bleached by the effects of long exposure, the petroleum content being entirely removed from this portion of the bed.

The first quarry near Bowling Green was opened by Belknap & Dumesnile, of Louisville, about seventy-five years ago. This was one, if not the first, of the quarries of oolitic limestone in the Southern States. Work is said to have been done here before any development in the Bedford district of Indiana. One of the earliest companies to begin operations in the vicinity of Bowling Green was the Bowling Green White Stone Quarry Company, the name of which is preserved to the present time. Before the construction of the Louisville and Nashville Railroad the stone was hauled and carried by pack mules to points as far south as Nashville. The corner posts and large gate pillars around the state capitol of Tennessee were constructed of this stone. The capitol building is made of local stone, which shows signs of disintegration, whereas the posts and pillars are little affected by more than fifty years of exposure to the weather.

Quarries now in operation on the "Bowling Green oolite" are as follows: The Bowling Green White Stone Quarry Company and the Oman Bowling Green Stone Company, on adjacent property 5 miles west of town; the Bowling Green Quarries Company, 5 miles northwest; and the Caden Quarry Company, 9 miles northwest of town. The total output of these quarries in the year 1908 was as follows: Rough dimension stone, 111,620 cubic feet, valued at $33,486; and dressed stone, 67,308 cubic feet, valued at $42,654. In connection with the work of the Bowling Green White Stone Quarry Company a considerable amount of the ordinary limestone capping the oolite is crushed for concrete, road metal, and railroad ballast by the Newsom Crushed Stone Company. Practically the entire output of dimension stone is shipped over the Louisville and Nashville Railroad, which is the only rail route; a small quantity is sent to market on barges by Barren and Green rivers.

The stone is quarried by means of steam drills and channelers, handled by steam derricks, and cut by rapid steam pitman saws to blocks averaging about 150 cubic feet in volume. The blocks are shipped in this form to retail stone cutters or dressed to various ornamental designs on the ground. Among prominent buildings constructed of this stone are the following: Custom-house, Nashville, Tenn.; Carnegie Library, Nashville, Tenn.; post-office, Columbia, Tenn.; custom-house, Mobile, Ala.; residences of Alfred Burke, Philadelphia, Pa., and A. M. Lothrop, Washington, D. C.

AVAILABLE STONE NEAR SOMERSET, KY.

In the vicinity of Somerset, Ky., there is a bed of homogeneous oolitic limestone about 25 feet thick. This stratum is in the Newman limestone, which outcrops in an extensive area in this section of the State. The writer made a reconnaissance of this bed in the hills east of the Southern Railway, discovering exposures which warrant the statement that the available stone is of sufficient quantity to justify commercial development. There is no marked disturbance of the strata in this region, the rocks being nearly horizontal and showing few vertical joints. It is probable that this field will be found an attractive one when brought to the attention of those financially interested in this phase of the building-stone industry. The only use of the stone has been by C. H. Lewis, of Somerset, who has quarried a small amount of oolite from Day Knob, 2½ miles east of Somerset, for certain ornamental designs and bases. The stone is similar to the Bedford and Bowling Green stones in general appearance. It is light gray, easily carved because of its granular structure, strong, and durable. Monuments of this stone in the local cemetery have undoubtedly been hardened considerably by exposure.

On the east side of Day Knob the oolitic bed is apparently about 29 feet thick, though a partial cover of débris did not permit a complete measurement at the time of the writer's visit. A clear section of 14 feet was exposed at the top of the bed and 5 feet at the bottom, with an intervening thickness of 10 feet concealed. At this point the oolite is capped by about 50 feet of hard bluish-gray limestone, but the low relief of the knob would permit a wide quarry face of much less overburden.

Three miles south of Somerset and just east of the Southern Railway there is a bed of oolite exposed at a suitable location for development. The writer could not be sure that this is the same bed as that exposed in Day Knob, but it probably is. In this locality the stone shows a thickness of 15 feet, covered by hard bluish-gray limestone. The topography is such that a zone approximately 100 feet wide could be worked over about 50 acres with a cover of not more than 20 feet.

This stone is of a grayish-white color and uniform texture, easily quarried and dressed. It should make a very durable building material and present an attractive appearance in walls of residences. The writer is of the opinion that it would, if properly placed on the market, command a ready sale in the cities of the Blue Grass region of central Kentucky.

OTHER EXPOSURES IN THE STATE.

Besides the areas above described, oolitic limestone is known to occur in the following counties of Kentucky: Barren, Simpson, Logan, Meade, Hardin, Grayson, Caldwell, Todd, Christian, Wolfe, Powell, and Rockcastle.

Of these counties, Barren and Caldwell have produced considerable stone from time to time from points near Glasgow Junction and Princeton. There is little doubt that the stone of these localities is approximately at the same horizon as the Bedford and Bowling Green stones. Oolitic limestone occurring near Princeton and Litchfield is described by G. P. Merrill[a] as follows:

The oolitic character is very pronounced in these stones, and while in some cases the production of a perfect surface is impossible, owing to the breaking away of these minute rounded grains, still in the better qualities the sharp edges and smooth surfaces are as readily acquired as on the celebrated Bedford (Indiana) or other stones of this character. These are superior to the Bedford stone, moreover, in their clear and uniform colors; Professor Proctor informs the writer that the stone is quarried with ease, is easily wrought, stands pressure well, and is considered one of the most reliable stones of the State.

A sample of the Barren County oolitic limestone near Glasgow Junction was collected by Prof. N. S. Shaler and analyzed by the state chemist.

Professor Shaler's note and the accompanying analysis are quoted below:[b]

A compact, nearly white, fine oolitic limestone, with a ferruginous stain on the exposed surfaces probably derived from the superincumbent soil.

Analysis of oolitic limestone from near Glasgow Junction, Ky.

Specific gravity	2.678
Lime carbonate	98.050
Magnesia carbonate	.363
Alumina, iron, and manganese oxides	.511
Phosphoric acid	.051
Sulphuric acid	.260
Potash	.115
Soda	.327
Silica and insoluble silicates	1.060
	100.737

[a] Stones for building and decoration, New York, 1903, pp. 308-309.
[b] Kentucky Geol. Survey, vol. 1, new series, 1876, p. 152.

The oolitic limestone, as shown by this analysis, is very high in calcium oxide, and is capable of supplying a clean, white lime when properly burned. Its purity and uniformity and the ease with which it is ground give it a desirable character for use in connection with shale and clay for the manufacture of Portland cement. The Kosmos Portland Cement Company, at Kosmosdale, Jefferson County, is using oolitic limestone from its quarries in Meade County. The stone is ground and mixed with Pleistocene clay of the inner valley of Ohio River. The following is an analysis of this stone made by B. Cushman, of Cornell University, and here quoted from the writer's report on Kentucky clays:[a]

Analysis of oolitic limestone from Meade County, Ky.

Calcium carbonate	98.49
Magnesium carbonate	.42
Silica	.37
Alumina	.12
Ferric oxide	.11
	99.51

The above analysis indicates a stone similar in composition to most oolitic limestones of the Mississippi Valley region.

CONCLUSION.

The oolitic limestone extensively quarried near Bowling Green, Ky., is very similar in character to stone of the same age at Bedford, Ind. The wide distribution of the stone offers opportunities for quarrying at many places in Kentucky favorably located for transportation. The stone has very few objectionable features, and its light-gray color will probably always be in fashion. Oolitic limestone has been used extensively as a building material in prominent structures, is approved by the United States Government in many federal buildings, and is surely growing in favor on the American market. It is therefore safe to predict a steadily increasing demand for this stone and the development of the more important Kentucky localities.

[a] Bull. Kentucky Geol. Survey No. 6, 1905, p. 21.

SURVEY PUBLICATIONS ON BUILDING STONE AND ROAD METAL.

The following list comprises the more important recent 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 213, pp. 357–360. 1903. 25c.

BAIN, H. F. Notes on Iowa building stones. In Sixteenth Ann. Rept., pt. 4, pp. 500–503. 1895. $1.20.

BURCHARD, E. F. Concrete materials produced in the Chicago district. In Bulletin 340, pp. 383–410. 1908.

——— Stone. In Mineral Resources U. S. for 1908, pt. 2, pp. 533–579. 1909.

——— Slate. In Mineral Resources U. S. for 1908, pt. 2, pp. 521–532. 1909.

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 213, pp. 361–364. 1903. 25c.

——— Notes on Arkansas roofing slates. In Bulletin 225, pp. 414–416. 1904. 35c.

——— Slate investigations during 1904. In Bulletin 260, pp. 486–488. 1905. 40c.

——— Note on a new variety of Maine slate. In Bulletin 285, pp. 449–450. 1906. 60c.

——— Recent work on New England granites. In Bulletin 315, pp. 356–359. 1907.

——— The granites of Maine. Bulletin 313. 202 pp. 1907.

——— The chief commercial granites of Massachusetts, New Hampshire, and Rhode Island. Bulletin 354. 228 pp. 1908.

——— The granites of Vermont. Bulletin 404. 138 pp. 1909.

DALE, T. N., and others. Slate deposits and slate industry of the United States. Bulletin 275. 154 pp. 1906. 15c.

DARTON, N. H. Marble of White Pine County, Nev., near Gandy, Utah. In Bulletin 340, pp. 377–380. 1908.

——— Structural materials in parts of Oregon and Washington. Bulletin 387. 36 pp. 1909.

DILLER, J. S. Limestone of the Redding district, California. In Bulletin 213, p. 365. 1903. 25c.

ECKEL, E. C. Slate deposits of California and Utah. In Bulletin 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 370. 99 pp. 1909.

KEITH, A. Tennessee marbles. In Bulletin 213, pp. 366–370. 1903. 25c.

LEIGHTON, HENRY, and BASTIN, E. S. Road materials of southern and eastern Maine. Bulletin 33, Office of Public Roads, Department of Agriculture. 1908. (May be obtained from Department of Agriculture.)

PAIGE, SIDNEY. Marble prospects in the Chiricahua Mountains, Arizona. In Bulletin 380, pp. 299–311. 1909.

RIES, H. The limestone quarries of eastern New York, western Vermont, Massachusetts, and Connecticut. In Seventeenth Ann. Rept., pt. 3 (continued), pp. 795–811. 1896.

SHALER, N. S. Preliminary report on the geology of the common roads of the United States. In Fifteenth Ann. Rept., pp. 259–306. 1895.

——— The geology of the road-building stones of Massachusetts, with some consideration of similar materials from other parts of the United States. In Sixteenth Ann. Rept., pt. 2, pp. 277–341. 1895. $1.25.

SIEBENTHAL, C. E. The Bedford oolitic limestone [Indiana]. In Nineteenth Ann. Rept., pt. 6, pp. 292–296. 1898.

SMITH, G. O. The granite industry of the Penobscot Bay district, Maine. In Bulletin 260, pp. 489–190. 40c.

CEMENT AND CONCRETE MATERIALS.

CEMENT MATERIALS IN REPUBLICAN VALLEY, NEBRASKA.

By N. H. Darton.

INTRODUCTION.

With the rapid growth of the cement industry in the United States many limestones are being investigated as to their suitability for cement manufacture. In order to obtain information of this kind an examination was recently made of a portion of the Republican Valley in Nebraska and samples of the limestone of the Niobrara formation were collected. It was found that these limestones could be quarried in large amount at various localities, and analyses show that some of them are well adapted to cement manufacture. Shale is plentiful at most places. Fuel is an important item in preparing cement, but unfortunately coal, which is the only fuel available here, is high priced in this region. It is possible that natural gas may be found, though several unsuccessful attempts to obtain it by deep borings have been made in northern Kansas. The low anticline which crosses the valley near Cambridge has not yet been adequately tested and may possibly yield either gas or oil when the lower strata are reached by the drill.

GEOLOGY OF THE REPUBLICAN VALLEY.

Several years ago a geologic reconnaissance of central southern Nebraska was made under the direction of the writer by G. E. Condra, and the results were set forth in considerable detail in his report.[a]

Southern Nebraska is underlain by several thousand feet of sedimentary strata—limestone, shale, and sandstone in a succession of widespread sheets. They lie nearly level, but have local variations

[a] Geology and water resources of the Republican River valley and adjacent areas: Water-Supply Paper U. S. Geol. Survey No. 216, 1907.

in dip which are not perceptible to the eye. The strata revealed in the Republican Valley dip gently westward except in the anticline in Furnas County, where from Oxford nearly to Cambridge the dips are very gentle to the east. The precise angle at which the strata are inclined has not been ascertained, but they descend only a few feet to the mile.

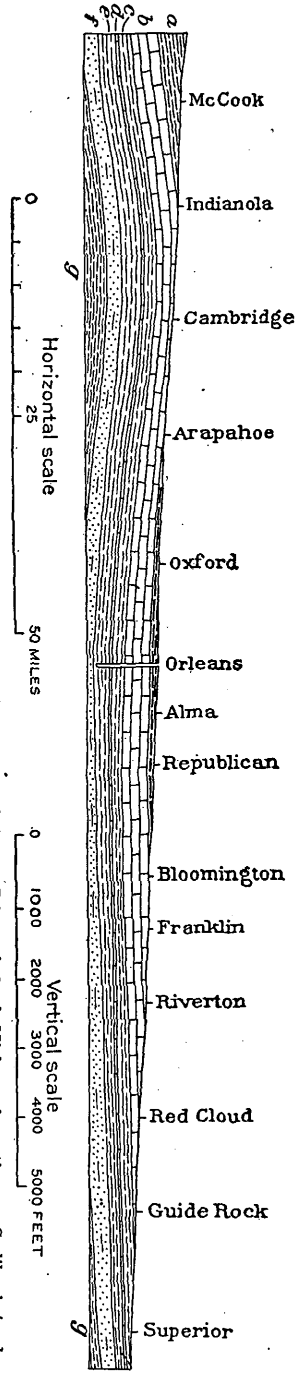

FIGURE 30.—Section along Republican Valley from McCook to Superior, Nebr., following the bluffs. *a*, Pierre shale; *b*, Niobrara formation; *c*, Carlile shale; *d*, Greenhorn limestone; *e*, Graneros shale; *f*, Dakota sandstone; *g*, Permian shale. The Quaternary loess and alluvium and Tertiary grit which cover most of the surface are not shown.

The formations exhibited are of Cretaceous, Tertiary, and Quaternary age, but deeper underground are shales and limestones of the Carboniferous. The Cretaceous rocks are the Dakota sandstone, about 300 feet thick; the Benton group, 300 to 600 feet; the Niobrara formation, 400 feet; and the Pierre shale, 1,000 feet. The Benton group consists of shale with a thin medial member of limestones, and only its upper formation, the Carlile shale, is exposed in the Republican Valley in Nebraska. The Niobrara formation, consisting of chalky limestones and limy shales, underlies all of the central Great Plains and in it is excavated the valley of Republican River. From Indianola to Superior, east of Guide Rock, the valley cuts into the underlying Carlile shale. At Indianola the westerly dip carries the formation beneath the Pierre shale in the bottom of the valley, and from a point near Arapahoe to Naponee the Pierre overlies the Niobrara in a shallow syncline, in places extending nearly to the valley bottom. These relations are shown in figure 30.

The shales and limestones in the Republican Valley region are largely covered by Tertiary grit and Quaternary loess on the adjoining table-lands and slopes and by the alluvium which fills the valley up to the level of the present flood plain. There is also more or less dune sand in part of the region.

LIMESTONE.

DISTRIBUTION.

The limestones of the Niobrara formation are the only ones of any value for cement manufacture in the Republican Valley. They lie at or near the surface through Webster, Franklin, and Harlan coun-

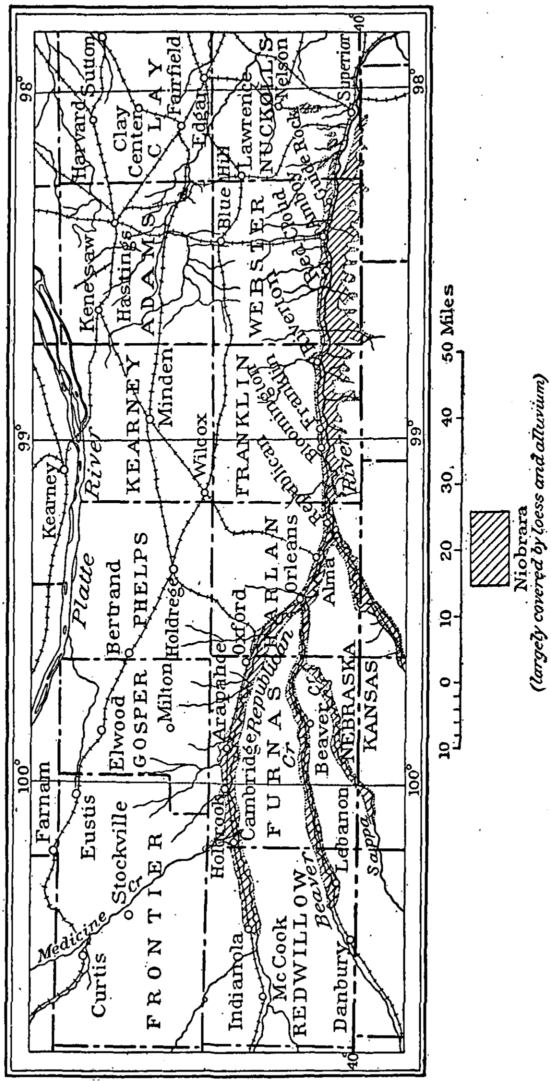

FIGURE 31.—Map showing outcrop area of Niobrara formation in south-central Nebraska. By N. H. Darton.

ties and the eastern half of Furnas County (see fig. 31), but owing to the heavy mantle of loess, talus, and alluvium, outcrops are rare. The most notable exposures are in the river bluffs from Franklin to Superior and in the anticlinal uplift near Cambridge. In the western part of Riverton 30 feet of the massive limestone is exposed and in the bluffs south of Red Cloud and Guide Rock and southwest of Superior there is much limestone. In Harlan County and the eastern part of Furnas County the formation is apparently below the level of the river flats, for the overlying Pierre shale is exposed at places down nearly to the water level. West of Arapahoe the chalky limestone again rises to the surface and on Medicine Creek, 3 miles north of Cambridge, it is so prominent that an extensive quarry has been developed. Southwest of Superior the edge of the formation passes southward into Kansas, but on the north side of the Republican Valley it is known to underlie much of the higher lands of Nuckolls County. Outcrops are revealed in draws north of Bostwick, south of Smyrna, at Nelson, and west of Angus.

ROCKS.

Although the Niobrara formation consists largely of limestone, some of the beds contain much clay. This material occurs mostly as an admixture in the impure "chalk rock," but some beds contain so much that they are calcareous shales. Ordinarily the Niobrara strata are interbedded deposits of soft limestone or chalk and calcareous clay from 5 to 30 feet thick. Flint occurs in the upper beds. Two members of the formation have been recognized. The lower one, averaging 50 feet in thickness and consisting mainly of soft limestone or compact chalk of light-gray color, represents the Fort Hays limestone of Kansas. The upper member consists of about 300 feet of alternations of soft "chalk rock" or chalky limestone and limy shales, all of light-gray color. The chalk-rock deposits vary greatly in thickness, in some places attaining 20 feet. This member represents the Smoky Hill chalk or "*Pteranodon* beds" of Kansas. A characteristic feature of the Niobrara rocks is their tendency to weather to a light-yellow color, though in their unweathered condition they are lead-gray or bluish gray.

COMPOSITION.

The limestone beds in the Niobrara formation vary greatly in composition owing largely to admixture of clay. The upper beds are cherty. Some representative samples were collected and analyzed in the laboratory of the United States Geological Survey with the following results, reported by S. S. Voorhees:

Analyses of limestone from the Niobrara formation in southern Nebraska.

	Riverton.	Two miles southeast of Red Cloud.	South of Guide Rock.	South of Superior.
Lime (CaO)	45.3	37.3	43.3	53.6
Magnesia (MgO)	.8	1.0	.6	.4
Carbon dioxide (CO_2)	35.2	29.3	33.9	42.5
Silica (SiO_2)	6.9	14.7	9.7	1.5
Alumina (Al_2O_3)	3.3	7.1	5.0	1.8
Iron oxide (Fe_2O_3)	1.0	1.7	1.7	.4
Sulphuric anhydride (SO_3)	1.6	.2	.04	.03
Sulphur (S)	.5	.6	.5	.0
Organic matter, etc	4.1	6.3	4.2	.7
	98.7	98.2	98.9	100.9
Lime carbonate ($CaCO_3$)	80.0	66.0	77.0	96.0

These analyses fully illustrate the variations in composition. The rock south of Superior is the massive limestone at the base of the formation, and its purity is notable. The other rocks contain considerable clay, which in the deposits south of Red Cloud is present in such large proportions that purer limestone would have to be added to bring the rock up to the Portland cement standard.

The calcareous grit of the Tertiary deposits covering parts of the high plains has been suggested as a source of Portland cement, but most of the material is too impure. This is shown by the following analysis of a highly calcareous grit from a quarry north of Cambridge not far from the quarry of Niobrara "chalk rock." The analysis was made in the laboratory of the United States Geological Survey and reported by S. S. Voorhees.

Analysis of calcareous grit from quarry north of Cambridge, Nebr.

Lime (CaO)	29.5
Magnesia (MgO)	.6
Carbon dioxide (CO_2)	23.8
Silica (SiO_2)	31.0
Alumina (Al_2O_3)	13.6
Iron oxide (Fe_2O_3)	.4

Much of the silica is in the form of sand grains. The carbonate of lime is too low by 20 per cent.

SHALE.

The Carlile shale, below the Niobrara formation, and the overlying Pierre shale both outcrop extensively in the Republican Valley (see fig. 30), although in many places they are covered by loess on the hillsides and alluvium in the valley. The Pierre shale appears in the banks near Indianola and extends up the valley into Colorado. There are many large exposures in the bluffs along the river, especially in the bends where the river cuts into the highlands on the south side of the valley. This shale also overlies the Niobrara formation in Harlan

County and the eastern part of Furnas County, but is rarely exposed. In some gullies 2 miles south of Orleans it may be seen extending down to the level of the alluvium in the valley bottom. The Pierre shale is nearly uniform in character, consisting of a mixture of clay and fine sand, the latter in somewhat variable proportions. The color is dark, owing largely to admixture with carbonaceous material. The shale is laminated in thin layers but on the surface generally appears as a bank of dark clay.

The Carlile shale, underlying the Niobrara formation, rises above the river level on or near the Webster-Nuckolls county line and appears extensively in slopes and bluffs south of Bostwick and Superior. It is somewhat harder than the Pierre shale and is of lighter-gray or greenish-gray color. The following analysis represents a sample collected in the hills south of Superior, a few feet below the limestone of which the analysis is given on page 385. It was made in the laboratory of the Geological Survey, and the results were reported by S. S. Voorhees.

Analysis of Carlile shale 5 miles southwest of Superior, Nebr.

Silica (SiO_2)	57.8
Oxide of iron (Fe_2O_3)	3.0
Alumina (Al_2O_3)	16.4
Lime (CaO)	.0
Magnesia (MgO)	1.2
Barium sulphate ($BaSO_4$)	1.5
Combined water	3.2
Organic matter	7.1

Considerable shale occurs in the Niobrara formation, most of it containing from 10 to 20 per cent of carbonate of lime.

CONCLUSIONS.

It has been ascertained that the limestone of the Niobrara formation in the Republican Valley is suitable for Portland cement manufacture. Much of it contains more than 75 per cent of carbonate of lime, and it is all very low in carbonate of magnesia, which is a deleterious constituent. It is doubtful if rock containing less than 75 per cent of carbonate of lime could be used except by admixture with purer rock to bring the average up to 75 per cent. Large quantities of the high-grade limestone are available, notably about Riverton and Red Cloud, in the hills southwest of Superior, and on Medicine Creek north of Cambridge. Shale occurs abundantly along the valley, but only in the region southwest of Superior were the limestone and shale found as near together as is desirable to supply a cement plant. There are, however, many localities farther west from which shale could be supplied by a very short shipment, notably the many shale bluffs along the river. No new information was obtained as to fuel. The discovery of oil or gas in the valley would be of greatest advantage, but there is no evidence that either of these fuels could be obtained. A recent boring in Orleans has a depth of 940 feet but failed to reach the Dakota sandstone, which lies but a slight distance deeper. The question as to the presence of oil and gas, especially in the anticline near Cambridge, should be settled by borings sufficiently deep to thoroughly test the shales and limestones that underlie the Dakota sandstone.

MATERIALS REQUISITE FOR CEMENT MANUFACTURE.

The following brief notes on requirements of cement materials probably will be of service to persons interested in the utilization of the deposits in southern Nebraska. The materials required for Portland cement as ordinarily manufactured are carbonate of lime and silicate of alumina—the former generally as limestone or chalk and the latter as shale or clay. Magnesia above 2 or 3 per cent and much sand, flint, or free silica in other forms, are deleterious constituents. The average proportion of carbonate of lime is 75 per cent and of clay 25 per cent. In some places such an admixture is found in the rock itself, but generally the materials are ground separately and mixed in the correct proportions. Ordinarily it would not be considered desirable to use a limestone containing less than 75 per cent of carbonate of lime, but such a rock could be used by admixture with purer limestone, provided the latter could be obtained cheaply. Some shales or clays contain too much fine sand to be used for the manufacture of high-grade Portland cement. The amount of coal used is from 200 to 300 pounds to the barrel (380 pounds) of cement.

The Niobrara chalk rock and overlying Pierre shale are used for cement manufacture at Yankton, S. Dak. This chalk rock contains 83 to 88 per cent of carbonate of lime. The following analyses of the cement materials at this place have been given:[a]

Analyses of Portland cement materials near Yankton, S. Dak.

	Chalk rock.		Shale.	
Lime (CaO)	52.16	51.00	5.28	1.57
Magnesia (MgO)	.14	Trace.	1.72	1.83
Carbon dioxide (CO_2)	41.64	37.99	3.09	....
Silica (SiO_2)	3.83	4.14	61.53	57.98
Iron oxide (Fe_2O_3)	....	2.72	4.01	4.57
Alumina (Al_2O_3)	2.31	1.81	20.74	18.26
Sulphur trioxide (SO_3)	.20	.50	1.26	1.28
Water	....	....	....	12.08

The Niobrara limestone is used extensively for Portland cement manufacture near Florence, Colo. Two kinds of rock are available—one averaging 71 per cent of carbonate of lime and occurring in beds 60 feet thick, and another containing about 88 per cent of carbonate of lime, of which there is a 40-foot bed.

[a] Eckel, E. C., Bull. U. S. Geol. Survey No. 243, 1905, p. 301.

GRAVEL AND SAND IN THE PITTSBURG DISTRICT, PENNSYLVANIA.

By Eugene Wesley Shaw.

INTRODUCTION.

In connection with the detailed geologic survey of several quadrangles in western Pennsylvania in 1908 and 1909, a careful study was made of the alluvial gravel and sand, and the present paper is a brief report on the geology of these extensive and valuable deposits. The area treated includes Beaver, Allegheny, and Armstrong counties. The gravel and sand are found on terraces and in the river bottoms and are of two distinct types, glacial and nonglacial.

The greatest amount of gravel digging has been done in Allegheny County, which has an area of 758 square miles, largely occupied by Pittsburg and its suburbs. In 1909, according to statistics gathered by the United States Geological Survey, this county produced approximately 2,300,000 tons of gravel and sand, the value of which f. o. b. at the point of shipment was over $630,000. These figures exceed those for the output of any other county in the United States; indeed, only seven States have productions as large as this one county. The sand and gravel resources of several near-by counties are almost as great as those of Allegheny County. Valuable deposits are found along the Allegheny and Ohio, on terraces and in the bottom lands, a large output being taken by dredges from the river beds. The accompanying map (fig. 32) shows the areal distribution of the valuable gravels in the vicinity of Pittsburg.

Western Pennsylvania is a hilly country, and although the river valleys are narrow they offer such uniform and low gradients for railroad building that they are used in preference to more direct routes across the hills. Towns and railroads both are crowded into the valleys, the rivers are navigable, and thus local markets and transportation facilities are in close relation with the gravel deposits. The closeness of this relation, together with the fact that the rocks of the region do not yield very desirable crushed stone, gives to the stream deposits their great commercial importance.

GEOLOGY.

GENERAL OUTLINE.

All gravel and sand is derived from consolidated rocks, and the different kinds owe their characters in part to differences in the parent rocks and in part to the geologic processes which have operated upon them. Well-rounded pebbles represent the most resistant parts of the mass from which they were derived. Soluble rocks, those with decomposable minerals or loosely cemented grains and those having pores or cracks, are broken up sooner or later; rocks of

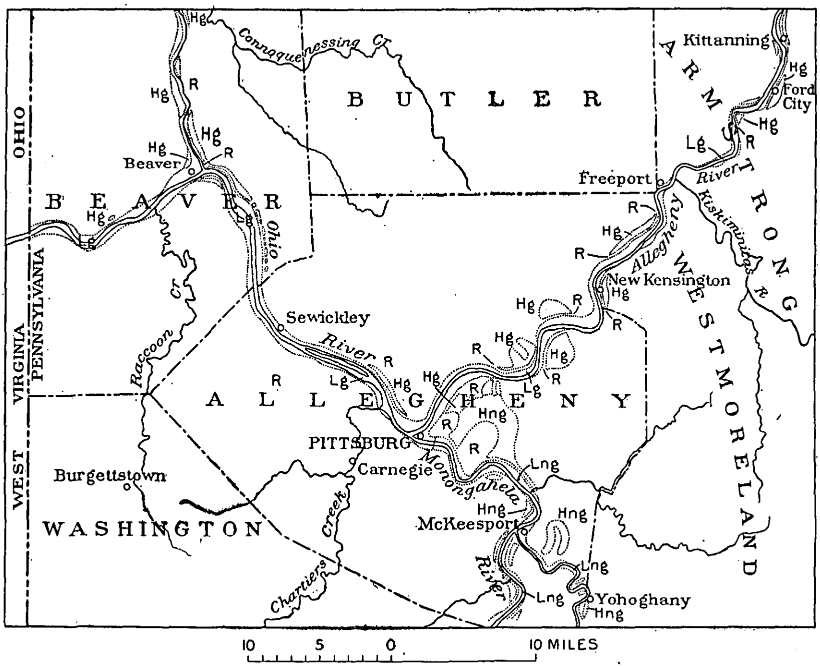

FIGURE 32.—Map showing principal areas of gravel deposits in the Pittsburg district, Pennsylvania. Hg, High glacial gravels; Lg, low glacial gravels; Hng, high nonglacial gravels; Lng, low nonglacial gravels; R, consolidated rock.

other kinds are preserved and concentrated. Of the resistant class quartz is the most common rock, and for this reason it is found in gravel and sand in much larger proportion than in the country rock. In some places, as, for example, at Canonsburg, quartz pebbles, although only rarely present in the consolidated rocks of the region, were found in a stream deposit where they had been concentrated like gold nuggets in a placer.

The present position of the deposits has also been determined by geologic processes. To illustrate, the sand of the Pittsburg district is of two principal varieties; that of the Allegheny and Ohio valleys is sharp and "hard" and that of the Monongahela Valley is "soft" and round grained. The difference is due to a difference in derivation. Much of the sand of the Allegheny and Ohio valleys comes almost direct from the igneous rocks of Canada, in which the quartz is entirely angular. On the other hand, all the material which the Monongahela carries has been derived from the sedimentary rocks that outcrop in its drainage basin. Most of the sandstones are not resistant and their grains have been reworked several times, so that they are now well rounded. Furthermore, upstream the deposits of the Monongahela decrease in thickness and the materials as a whole are much finer, only the basal portion being as coarse as the glacial gravels of the Allegheny Valley. Most of the rocks that outcrop in the Monongahela basin belong to the Carboniferous system, and the strata consist of micaceous, fine-grained sandstone, generally not very resistant, limestone, shale, and a small amount of conglomerate. The alluvial material derived from these rocks is largely a fine sandy mud, with numerous interbedded lenses of slightly calcareous sand and rounded quartz pebbles.

TERRACE GRAVELS.

Extensive bodies of high-terrace gravels lie on a rock floor 200 feet above the rivers. The glacial and nonglacial gravels are of approximately the same age, but as they have had different origins and are adapted to different uses, they will be treated separately.

EARLY GLACIAL GRAVELS.

The early glacial gravels are found on high rock terraces along the Allegheny and Ohio and have a maximum thickness of over 100 feet. The formation is made up of a heterogeneous mass of well-weathered gravel and sand, varying in kind of rock and in size of pebbles and grains. In many places the basal part is cemented into conglomerate. Some of the pebbles are of granite, diorite, and other igneous rocks, and these must have come from Canada. Others are of the peculiar deep-red Medina sandstone that outcrops in New York but not within the drainage basin of the Allegheny. Some contain silicified fossils, which show them to have been derived from pre-Carboniferous limestones that outcrop in New York but not in western Pennsylvania. Still others are of local origin, having been derived from the layers of hard rock, particularly sandstone, which outcrop abundantly in the region. All these pebbles are mingled with a mass of sand, silt, and clay, the proportionate amount of coarse material being greater than in the nonglacial gravel.

The following section was measured at the gravel pit on Woodlawn avenue, Allegheny, where the elevation of the surface is 232 feet above the river.

Section of high glacial gravels in Allegheny, Pa.

	Feet.
Silt, fine, without pebbles	10
Clay, yellow, and small sand lenses	1–2
Sand and gravel, well-washed pebbles, mostly 0.01 inch to 2 inches in diameter	4–5
Gravel, pebbles, and bowlders up to 4 feet in diameter in a matrix of sand and clay	4–7
Gravel and sand, well washed, with cross-bedding planes sloping downstream	2–3
	24

Above the main body of gravel there are scattered pebbles of local origin, probably remnants of much older stream deposits that have been almost entirely destroyed. Small bodies of local gravel have been found also at some places along the hillward side of the deposit and at many places at the base. These are likewise remnants of preglacial stream deposits. With the exception of the quartz all the pebbles of these very old gravels are so decomposed that they can be crushed in the fingers.

The upper limit of glacial gravel in the vicinity of Pittsburg is about 300 feet above the river. The original upper surface of the formation was at about this position. Up the Allegheny this surface gradually rose, and near Kittanning it was 50 feet higher than at Pittsburg. As a result of erosion the present upper limit of the gravel is not a plane, but the formation thins out irregularly. Probably more than nine-tenths of the original deposit has been carried away by erosion, but many of the most resistant pebbles from it are to be found to-day in lower gravel formations. At present the gravel is found in many isolated deposits, which range up to a mile or more in width and up to 100 feet or more in thickness.

The events which led to this great accumulation of gravel seem to be as follows: An early continental ice sheet, probably the Kansan, covered much of northwestern Pennsylvania to a depth of thousands of feet, stopping all northward drainage and forcing the streams to find outlets to the south. In the readjustment of drainage new parts of valleys were cut, and this process yielded considerable volumes of débris. At the same time the glacier was bringing its load of rock and earth from Canada and New York, and the streams became overloaded. However, the rivers were larger than they are at present, for they were carrying the run-off of all the precipitation that fell on the country south of the area in Canada which formed the center of glacial radiation.

Most of the present valley of the Allegheny and Ohio as far as Beaver was in preglacial time occupied by a smaller river which flowed about 200 feet higher than the present streams. At that time the valley was thus only about half as deep as at present but was nearly a mile wide at the base. With the advent of glaciation alluvial deposits accumulated to a depth of more than 100 feet, although throughout the time during which the overloaded condition lasted the river was carrying away material as rapidly as possible. After the ice disappeared and gradients became somewhat adjusted the overburden decreased, and finally the river was able not only to carry its load but to pick up some that it had dropped. Later it was able to cut down into the hard rock below, to a position 50 feet lower than the present channel. A large part of the old gravel deposit and the older valley bottom beneath has thus been destroyed and the remnants form to-day a high, gravel-capped rock terrace.

NONGLACIAL HIGH-TERRACE DEPOSITS.

High terraces are found also along the Monongahela and other large streams tributary to the Ohio and Allegheny. They are capped with a deposit of sand, clay, and silt, in which are embedded many pebbles and bowlders of sandstone, some of quartz, and a very few of other rocks, but none of glacial material. In general, the coarsest part of the formation is found at the base, and this part is in some places cemented into conglomerate by iron oxide. Above this the central part, comprising more than half the thickness, is made up of sand and silt, with embedded pebbles, many of them flat and arranged in parallel slanting positions. The pebbles are abundant in certain lenticular layers, but in other parts are almost entirely absent. The uppermost layers of the formation are commonly composed of sand and silt. A very few lenses are approximately free from clay. Nearly all parts of the formation contain too much fine material to be valuable as sources of gravel.

Several different views have been held concerning the origin of these high nonglacial deposits and the topographic features connected with them. Some of the earliest workers believed that the terraces were due to submergence and marine erosion. Others have ascribed the deposits to a large ice dam at Cincinnati or Beaver. Still others look upon these features as the result of stream work, but do not go into details of development; and at least one worker believes that certain of the abandoned parts of valleys owe their existence to huge local dams of ice. The writer has presented the view that all the high-terrace deposits were developed as a unit, through the overloading of the Allegheny and Ohio in glacial time, the deposits on those streams choking the tributaries and causing them to partly fill the lower ends of their valleys.

INTERMEDIATE TERRACE GRAVELS.

Below the high terraces and above the present flood plains, particularly on the Allegheny and Ohio, there are at many places terraces of varying age, but younger than the early glacial and older than the recent. Commonly there is no perceptible rock shelf under them, and the deposits are composed of gravel, sand, clay, and silt, not so deeply weathered as the higher deposits. In few places does the thickness exceed 15 feet. Some of the deposits may mark an overloaded stage of the river, or all may be remnants of ordinary flood-plain deposits made in the course of the stream's downward cutting. They are of too small extent to be of commercial value.

LATE GLACIAL GRAVEL.

Along Allegheny and Ohio rivers is a continuous thick deposit of gravel derived from a great variety of rocks occurring in Canada, New York, and Pennsylvania. Much of the material has been reworked by the streams and might properly be called recent alluvium, but the original deposit and the reworked part are so much alike in constitution and lie so nearly at the same position that for present purposes they are better treated together. This gravel is the most valuable in the region and extends from approximately 100 feet above low water to 50 feet below. The present thickness ranges up to about 130 feet, and probably the original thickness was slightly greater. The pebbles and bowlders are well rounded and constitute the most conspicuous part of the formation. In diameter they range up to a foot or more, though most of them are between 1 and 3 inches. The proportion of different kinds of rocks varies. Sandstone is most abundant; quartz and igneous rocks are present in nearly equal amounts; chert pebbles are numerous. Some well records indicate that the coarseness increases with increasing depth; others that the proportion of sand and silt increases down to the basal layers, which are generally coarse. However, all the pebbles are embedded in a matrix of sand and clay, and even where they are coarsest there is considerable interstitial space occupied by the finer materials. The pebbles are much less deeply weathered than those found on the high terraces, and the upper surface of the later deposit has not been so profoundly modified by the streams.

The largest area of late glacial gravel is found in the lower part of the city of Allegheny, and in this connection it is interesting to observe that certain characters and relations of this formation give it an important geographic bearing. Its surface is level but easily excavated, and although above the reach of high water, yet it is near the river, a position which is important with respect to water supply, power, and commerce; it contains immense supplies of sand and gravel; it is usually present along both sides of the river; and though throughout most of its extent it is narrow it locally broadens to a mile or more and thus presents admirable sites for towns, manufacturing plants, and railroads.

The following well section is typical. The elevation of the surface at the well is 70 feet above the river.

Well section at Sewickley, Pa.

	Feet.
Silt, gravelly, yellow	9
Gravel, coarse	4
Sand	8
Sand, gravelly	40
Mud, blue	8
Sand and gravel	25
Sand and bowlders	14
	108

The mode of development of the lower glacial gravel seems to be similar to that of the higher gravel. In interglacial time the rivers had apparently cut to 50 feet or so below their present position. With the advent of one of the late ice sheets, probably the Wisconsin, the Allegheny and Ohio again became overloaded with débris and again built a valley train, thicker than the earlier though not so broad. The volume of the lower deposit was probably somewhat smaller than that of the earlier gravel, but so much less of the later material has since been carried away that at present it is much more important. Though the Ohio is a large and powerful river, it has not yet cut through the deposit to its former position and is still laboring with its glacial burden.

Thus the lower gravel marks a time when the rivers, being overloaded with glacial débris, left some of the coarser, less easily transported material in their beds and along their banks, and in this way partly filled their valleys. The numerous bowlders of sandstone from near-by districts, ranging up to 4 or 5 feet in diameter, suggest that the rivers were somewhat larger than now; indeed, it is likely that they were to a greater or less degree glacial torrents.

The pebbles are the most resistant parts of the many kinds of rocks which are within reach of transportation or which outcrop to the north. They have traveled far, the journeys and the age of the most resistant being the greatest.

LATE NONGLACIAL GRAVEL.

The lower reaches of the Monongahela and other tributary streams flow over beds of gravel which, except for their slight weathering, closely resemble the nonglacial high-terrace deposits. Near Pittsburg the base of this late nonglacial gravel lies about 45 to 50 feet below and the upper limit 100 feet above low water. Upstream the deposit rises and thins, and at the West Virginia line it has the thinness and other characters of an ordinary flood-plain deposit. The Monongahela does not flow on a bed-rock channel anywhere within the State of Pennsylvania. At many places the river has swung into the side of the valley, leaving the deposit on the opposite side, and has laid consolidated rock bare, but nowhere does hard rock extend across the full width of the river.

The late nonglacial gravel contains considerable bodies of clean sand and many of these have been worked. The sand differs from the sand of Allegheny River in being round grained. The pebbles are also well rounded. Many of them are rather flat, but few are angular. On the whole, there is much more fine material in this deposit than in the late glacial gravel.

Where covered with water the upper 2 or 3 feet of gravel and sand harden in a way that suggests cementation. On exposure to the air the sand again becomes loose. Hardening is said to take place in about three years.

The following well section at McKeesport illustrates the character of the deposit. The elevation of the well is 40 feet above the river.

Section of well at McKeesport, Pa.

	Feet.
Silt, sandy	8
Sand, with quartz pebbles and sandstone bowlders	11
Sand, with some silt	20
Mud, blue	11
Sand, with quartz and sandstone pebbles	19
Sand, clean	8
Mud, sandy with many bowlders	12
	89

DEVELOPMENT.

The alluvial gravel and sand of the Pittsburg district are worked and prepared by two principal methods. The larger part of the production is dredged from the river bottom and a smaller part is taken from ordinary pits.

DREDGING.

In dredging, a favorable spot is chosen where the gravel is loose and of desirable quality. The material is brought up by bucket endless chains and is screened and washed with one handling. Gravel is usually loaded on barges on one side of the dredge, while sand is loaded on the other. Several different sizes of gravel are produced. A 3-inch mesh screen is used for general heavy concrete gravel; 1½ inch for material for sidewalks and small reinforced concrete. Frequently ¾-inch gravel also is screened out. The average amount of gravel and sand obtained in the material worked is variously estimated at 15 to 30 per cent. It is often said that the bowlders and fine waste occupy almost as much space as the original deposit. In ordinary stages of the river dredging operations are carried on more extensively on the Allegheny, but in times of low water most of the gravel is taken from pool No. 1 on the Ohio. A small amount is taken every year from the Monongahela, but the sand and gravel of this stream are of so much lower value that the deposits are not worked extensively.

If it were not that the river were constantly bringing in fresh supplies of valuable gravel and uncovering new bodies, the bed of the river would soon be picked over and the available deposits so depleted as to be worthless, but although millions of tons of gravel and sand have been taken from the rivers, the only effect has been to reduce the proportion of available material. Several miles away somewhat "better picking" is now found than in the vicinity of Pittsburg. From points 35 miles or more up the Allegheny gravel is being brought to Pittsburg, and dredging for local markets is carried on at a considerably greater distance.

STRIPPINGS AND PITS.

Several large strippings and numerous small pits are opened on the extensive flood plain and terrace deposits of the area, but the yield from these openings is much smaller than that from the river beds. The principal reason is that the expense of working the land deposits is considerably greater than the cost of dredging, but an additional reason is that the gravels, particularly those on the high terraces, are somewhat decayed and therefore not so valuable as the product of the river bed. Nevertheless the terrace deposits are worth working, and operations on them are increasing in extent as the more valuable and more easily accessible parts of the river gravels are exhausted. At an extensive stripping on Woodlawn avenue, Allegheny, about 15 feet of naturally well-washed sand and gravel are worked. The overburden is here 10 feet or more thick and is removed by scrapers. Most of the pebbles are under 2 inches in diameter, but many are larger and there are a few bowlders 3 to 4 feet in diameter. The sand grains consist almost exclusively of quartz. Among the pebbles sandstone predominates, but quartz is abundant and igneous and metamorphic rocks are common. Small lenses of sand are numerous. There are also cherty pebbles, probably from the Onondaga limestone of New York, deeply decayed "Corniferous" limestone pebbles, and a few pebbles of Silurian rocks.

About half a mile east of the Woodlawn avenue pit is another, showing 3 to 4 feet of nearly white clay at the base, overlain by well-washed gravel, with pebbles mostly 1 to 2 inches in diameter but many smaller. The deposit contains a few subangular sandstone bowlders which have probably not traveled far. Pebbles of igneous rock are common, and there are a few of conglomerate and many of quartz. Fossiliferous pebbles from New York are numerous. The gravel is screened by hand, the meshes of the screens being about 3 inches and one-fourth inch.

In Pittsburg, near the United States arsenal and Liberty street, the James Jiles Company works a gravel for mill and foundry sand. The whole deposit, including sand, gravel, and silt, is ground together. A short distance away Evan Jones & Co. make paving brick of the terrace clay and sand. There are many other pits, but these are typical and give a fair idea of the character of the deposit and the methods of working.

USES.

Immense quantities of gravel have been used in street foundations in this region. Almost the entire length of Pittsburg's 300 miles of streets is founded upon a gravel base having an average thickness of 9 inches. Possibly a still larger amount has been used in concrete. The Government has built 12 locks on the rivers of this district, and the average quantity of gravel and sand used in each was 50,000 cubic yards, or approximately 67,500 short tons. The gravel seems to be quite satisfactory in concrete work, 25 per cent of good cement generally being used. The concrete made in this way will break across the pebbles and not around them.

In many parts of the United States gravel is extensively used as railroad ballast, but in the vicinity of Pittsburg the iron and steel works yield large quantities of slag and the railroads use this material for ballast.

The new filtration works at Pittsburg will use 68,300 cubic yards of filter gravel and 245,900 cubic yards of filter sand. There are fifty-six 1-acre filters and each is to have a basal layer of gravel about a foot thick and an upper layer of sand about 2½ feet thick. The gravel is of four sizes and was bought by contract at two different times for $1 and $1.74 a cubic yard. The sand was also bought by contract, the prices paid being 85 cents and $1.49 a cubic yard. All of the filter material is being obtained from the bed of Allegheny River, opposite the filtration works, about 7 miles above the junction of the Allegheny and the Monongahela. At this place the river-bed deposit conforms so closely with the requirements for filter sand and gravel that very little screening and washing is necessary. The following quotation[a] gives the principal specifications for filter material at these works:

FILTER GRAVEL.

SEC. 20. Four different classes of filter gravel shall be used as hereinafter specified. Filter gravels known as Nos. 1 and 2 may be hard, durable stone, broken and screened to the proper sizes, or gravel screened from river deposits or banks of a sandy nature. Filter gravels known as Nos. 3 and 4 shall be rounded gravel only, screened from deposits of a sandy nature. Filter gravels Nos. 1, 2, and 3 shall be rendered free from sand.

[a] Contract and specifications for filter material for additional filters, situate in O'Hara Township, Allegheny County, Pa. (contract No. 11-H, city of Pittsburg, Pa.), Department of Public Works, Bureau of Filtration, 1908, pp. 42, 43, 46, 47.

Gravel screened from hardpan or clayey materials can not be sufficiently cleaned. Broken stone or gravel shall not be of or contain more than a small amount of shale or imestone. Broken stone shall be of well-formed, nearly rectangular stones, and shall not contain thin, flat, or long, sharp angular pieces.

SEC. 21. Filter gravel shall not contain more than 2 per cent of lime and magnesia and other matter soluble in water or a weak solution of hydrochloric acid, taken together and calculated as carbonate.

SEC. 22. The filter gravel shall be divided into four classes known as Nos. 1, 2, 3, and 4. Each class shall be uniformly graded and shall meet the requirements given in the following table, screening being performed with rated sieves in the manner now being used by the bureau. Sizes down to and including seven sixty-fourths of an inch will be measured by means of finished plates having circular holes whose diameter is the specified size. For sizes under seven sixty-fourths of an inch, sieves will be used having a clear mesh of the specified size.

Size.	No. 1 gravel.		No. 2 gravel.		No. 3 gravel.		No. 4 gravel.	
	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.
100 per cent shall pass	3	76.2	$1\frac{1}{2}$	38.1	$\frac{1}{2}$	12.7	$\frac{3}{16}$	4.8
100 per cent shall be retained on	$1\frac{1}{2}$	38.1	$\frac{1}{2}$	12.7	$\frac{3}{16}$	4.8	......	1.8
Not more than 10 per cent shall pass	$1\frac{9}{16}$	39.7	$\frac{19}{32}$	15.1	$\frac{7}{32}$	5.6	......	1.0
At least 10 per cent shall pass	$1\frac{31}{32}$	50.0	$\frac{13}{16}$	20.6	$\frac{9}{32}$	7.1	......	1.8

FILTER SAND.

SEC. 31. Sand before it is distributed in the filters and from that time until final acceptance shall have a cleanliness represented by the following conditions: When 100 grams of filter sand are thoroughly shaken up in a beaker containing 1 liter of distilled water, the resulting turbidity of the water shall not exceed 200 parts per million by the silica standard. Sand showing a cleanliness less than this will be rejected.

SEC. 32. Filter sand shall be clean Allegheny River sand, or its equivalent in all respects, and shall not contain over 1 per cent by weight of flat, laminated, or micaceous particles. It shall be entirely free from clay, dirt, coal, or organic impurities and shall be screened and washed to remove such materials. All grains shall be of hard material which will not disintegrate.

SEC. 33. Filter sand shall contain at least 92 per cent of silica and insoluble residue and shall not contain more than $1\frac{1}{2}$ per cent of lime and magnesia, taken together and calculated as carbonates; all being determined by treating the sand by boiling with 10 per cent of hydrochloric acid. Other conditions being equal, preference will be given to the sand which is lightest in color.

SEC. 34. The filter sand shall be of uniformly graded material from coarse to fine and conform to the following requirements as to size. The diameter of the sand grains shall be computed as the diameters of spheres of equal volumes.

Not more than one-half of 1 per cent by weight shall be less than 0.16 millimeter; not more than 10 per cent by weight, less than 0.28 millimeter; at least 10 per cent by weight shall be less than 0.36 millimeter; not more than 60 per cent by weight shall be less than 0.6 millimeter; at least 60 per cent by weight shall be less than 0.75 millimeter; and at least 90 per cent by weight shall be less than 2.1 millimeters. No particles shall be more than 5 millimeters in diameter, and the sand shall be passed through screens or sieves of such mesh as to stop all such particles, and no screens or sieves shall be used which contain at any point holes or passages allowing grains larger than 5 millimeters to pass.

Some of the Allegheny River sand is usable for grinding plate glass. Uniformity of size seems to be an important requirement of sand for this purpose. At Ford City large quantities are used until ground fine and then washed back into the river. However, much of the river sand is not suitable for this work. Certain sands seem to be desirable in purity, size, and angularity of grain and appear to the untrained eye to be like that which is used successfully, but are nevertheless worthless, because they contain here and there coarse grains known to the operators as "lice." The sand of the Allegheny Valley is also used for many other purposes, including molding, building, and filtration. Furnace, engine, and fire sands and other kinds are produced in less quantity. The sand of Monongahela River is used in grout, for furnace bottoms, in mills, and in street paving.

The high-terrace deposits of the Monongahela are less valuable than those of the Allegheny and have not been worked extensively. They are, however, used locally in many areas; for example, sand and silt from these terraces were used for the diamond of the new baseball park in Pittsburg.

PRODUCTION AND VALUE.

The following table gives the amount and value f. o. b. at the point of shipment of the stream sand and gravel produced in Allegheny, Beaver, and Armstrong counties in 1909:

Production of stream sand and gravel in Allegheny, Beaver, and Armstrong counties, Pa., in 1909.

	Quantity (short tons).	Value.
Sand:		
Molding sand	107,550	$81,225
Building sand	1,047,963	345,713
Sand for grinding plate glass	144,467	78,284
Other sands, including fire, engine, furnace, and filtration sands	10,550	6,010
Gravel	1,254,631	210,831
	2,565,158	722,063

In this region the highest priced stream-laid sand is that sold for filtration purposes, and this brings over $1 a ton. The others, in order of their value, are fire sand, engine sand, furnace sand, molding sand, sand for grinding glass, and building sand, the last named selling for about 30 cents a ton. The average selling price of gravel f. o. b. at the point of shipment is about 15 cents a ton, or half the price of the cheapest sand. Retail dealers deliver gravel in small amounts for about 8 cents a hundred pounds.

The demand for sand and gravel will probably continue to increase, and as the river-bed deposits become thoroughly picked over and the better and more easily accessible parts become exhausted, attention will be turned to the higher deposits, which contain much valuable material, are well drained, have generally little overburden, and may be easily worked by hand or steam shovel.

SURVEY PUBLICATIONS ON CEMENT AND CEMENT AND CONCRETE MATERIALS.

The following list includes the principal publications on cement materials by the United States Geological Survey, or by members of its staff. The government 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. Besides the publications cited, the Survey has in preparation bulletins dealing with the results of tests on concrete beams and the constituent materials of concrete, etc.

ADAMS, G. I., and others. Economic geology of the Iola quadrangle, Kansas. Bulletin 238. 80 pp. 1904.

BALL, S. H. Portland cement materials in eastern Wyoming. In Bulletin 315, pp. 232–244. 1907.

BASSLER, R. S. Cement materials of the valley of Virginia. In Bulletin 260, pp. 531–544. 1905. 40c.

BURCHARD, E. F. Portland cement materials near Dubuque, Iowa. In Bulletin 315, pp. 225–231. 1907.

——— Concrete materials produced in the Chicago district. In Bulletin 340, pp. 383–410. 1908.

BUTTS, C. Sand-lime brickmaking near Birmingham, Ala. In Bulletin 315, pp. 256–258. 1907.

——— Ganister in Blair County, Pa. In Bulletin 380, pp. 337–342. 1909.

CATLETT, C. Cement resources of the valley of Virginia. In Bulletin 225, pp. 457–461. 1904. 35c.

CLAPP, F. G. Limestones of southwestern Pennsylvania. Bulletin 249. 52 pp. 1905.

CRIDER, A. F. Cement resources of northeast Mississippi. In Bulletin 260, pp. 510–521. 1905. 40c.

——— Geology and mineral resources of Mississippi. Bulletin 283. 99 pp. 1906.

DARTON, N. H. Geology and water resources of the northern portion of the Black Hills and adjoining regions in South Dakota and Wyoming. Professional Paper 65. 104 pp. 1909.

——— Structural materials in parts of Oregon and Washington. Bulletin 387. 36 pp. 1909.

DARTON, N. H., and SIEBENTHAL, C. E. Geology and mineral resources of the Laramie Basin, Wyoming. Bulletin 364. 81 pp. 1908.

DURYEE, E. Cement investigations in Arizona. In Bulletin 213, pp. 372–380. 1903. 25c.

ECKEL, E. C. The materials and manufacture of Portland cement. In Senate Doc. 19, 58th Cong., 1st sess., pp. 2–11. 1903.

——— Cement-rock deposits of the Lehigh district. In Bulletin 225, pp. 448–450. 1904. 35c.

——— Cement materials and cement industries of the United States. Bulletin 243. 395 pp. 1905. Edition exhausted. Available for reference in libraries of cities and educational institutions.

——— The American cement industry. In Bulletin 260, pp. 496–505. 1905. 40c.

——— Portland cement resources of New York. In Bulletin 260, pp. 522–530. 1905. 40c.

——— Cement resources of the Cumberland Gap district, Tennessee-Virginia. In Bulletin 285, pp. 374–376. 1906. 60c.

——— Cement industry in the United States in 1908. In Mineral Resources U. S. for 1908, pt. 2, pp. 441–453. 1909.

ECKEL, E. C., and CRIDER, A. F. Geology and cement resources of the Tombigbee River district, Mississippi-Alabama. Senate Doc. 165, 58th Cong., 3d sess. 21 pp. 1905.

HUMPHREY, R. L. The effects of the San Francisco earthquake and fire on various structures and structural materials. In Bulletin 324, pp. 14–61. 1907. 50c.

——— Organization, equipment, and operation of the structural-materials testing laboratories at St. Louis, Mo. Bulletin 329. 85 pp. 1908.

——— Portland cement mortars and their constituent materials: Results of tests, 1905 to 1907. Bulletin 331. 130 pp. 1908. 25c.

——— The strength of concrete beams; results of tests made at the structural-materials testing laboratories. Bulletin 344. 59 pp. 1908.

——— The fire-resistive properties of various building materials. Bulletin 370. 99 pp. 1909.

LANDES, H. Cement resources of Washington. In Bulletin 285, pp. 377–383. 1906. 60c.

MARTIN, G. C. The Niobrara limestone of northern Colorado as a possible source of Portland cement material. In Bulletin 380, pp. 314–326. 1909.

PEPPERBERG, L. J. Cement material near Havre, Mont. In Bulletin 380, pp. 327–336. 1909.

RICHARDSON, G. B. Portland cement materials near El Paso, Tex. In Bulletin 340, pp. 411–414. 1908.

RUSSELL, I. C. The Portland cement industry in Michigan. In Twenty-second Ann. Rept., pt. 3, pp. 620–686. 1902.

SEWELL, J. S. The effects of the San Francisco earthquake on buildings, engineering structures, and structural materials. In Bulletin 324, pp. 62–130. 1907. 50c.

SMITH, E. A. The Portland cement materials of central and southern Alabama. In Senate Doc. 19, 58th Cong., 1st sess., pp. 12–23. 1903.

——— Cement resources of Alabama. In Bulletin 225, pp. 424–447. 1904. 35c.

TAFF, J. A. Chalk of southwestern Arkansas, with notes on its adaptability to the manufacture of hydraulic cements. In Twenty-second Ann. Rept., pt. 3, pp. 687–742. 1902.

CLAY.

FULLER'S EARTH AND BRICK CLAYS NEAR CLINTON, MASSACHUSETTS.

By William C. Alden.

During the final melting of the Pleistocene glacier from central Massachusetts considerable bodies of water were held by the retreating ice front in some of the valleys which formerly discharged toward the north. The largest of these temporary glacial lakes, to which W. O. Crosby has given the name Glacial Lake Nashua, occupied the valley of Nashua River in the vicinity of Clinton, Mass. There were several stages of this lake, due to the opening of successively lower outlets as the ice front retreated northward. These stages were characterized by extensive deposition of sand, gravel, and silt.

The history and deposits of this ancient glacial lake have been discussed by Professor Crosby[a] in connection with studies covering the building of the Wachusett reservoir dams. They are also treated in the forthcoming Quinsigamond folio of the Geologic Atlas of the United States.

The deposits representing the latter part of the Clinton stage of this lake are fine laminated silts, now overlain by sand and gravel of a terrace of a later stage. The best exposure of these clays is at the New England Brick Company's plant, half a mile west of Still River station, where an excavation is being made in the abrupt margin of a broad terrace. The upper 10 to 12 feet consists of cross-bedded sand and fine gravel, forming the terrace top. Beneath this material and above the level of the floor of the valley is exposed 12 to 14 feet of blue, stoneless, laminated clay, with alternate layers slightly sandy and less dense. The depth to which this clay extends below the level of the valley floor is not known, but at one point a low ridge of stony blue clay rises a few feet above the floor, and the laminæ of the clay above dip with the slope of its surface. About the middle of the section are three beds, 1½ feet, 1 foot, and 10 inches in thickness, in which the laminæ are closely crumpled in little folds.

[a] Tech. Quart., vol. 16, 1903, pp. 240-254; vol. 17, 1904, pp. 37-75.

Between, above, and below these beds are regular undisturbed laminæ. The little folds are not regularly overthrust toward the south, there is no coarse or unassorted drift on the several contorted layers, nor is there other evidence of a readvance of the ice front, such as would indicate that the glacier had thrice overridden the laminated silts. It is more probable that the contortions were caused by repeated groundings of icebergs or ice floes on the soft clay bank. The rising, sinking, and turning of such grounded masses with the movement of the water might contort the clay laminæ to a depth of a few inches, as is seen here. Continued deposition after each interruption covered the disturbed beds with regular laminæ. The clay is exposed in the bank for some distance northward. Just south of the pit the surface of the clay drops down in the section, so that for some rods north of the road the whole section is made up of stratified sand and gravel. Similar clay is also exposed at an old brickyard on the east side of the valley about three-fourths of a mile north of Still River station. It is reported that clay was dug for brick some thirty years ago in the lower slope east of Whittemore Hill, at the Burbank place.

One mile northeast of Lancaster, just east of the railway, a pit owned by E. and R. M. Farnsworth exposes 8 feet of laminated clay beneath 5 feet of sand and gravel. Except the upper 1 foot, which contains some pebbles, the clay is almost wholly without stones, though a few berg-dropped bowlders are present in the deposit. It is said that a thickness of at least 26 feet was shown at one point by excavation and boring, and that the deposit thins up the slope to 8 feet at the west side of the railway, the average being perhaps 15 feet. Lower down the slope to the east the stony blue till is exposed. The laminæ of the clay are slightly undulating, and it is said that in places in digging they have been found folded and tipped up on edge. These laminated silts were evidently deposited in the open lake and not in the immediate vicinity of the ice front, being free from coarse detritus except that dropped from floating ice. It is believed that they were laid down in the waters of the Clinton stage of the lake, while the ice front stood at the moraine 2 or 3 miles north of Still River station. The material is used for fuller's earth and is, so far as the writer has ascertained, the only glacial silt so used anywhere. It is also reported that this clay is being used as a binder in the manufacture of emery stones.

Lacustrine clays adapted to brick manufacture in this region appear to be confined to the Nashua Valley north of Clinton, though they may occur in other basins beneath the coarser sand and gravel or marsh deposits. The blue clay taken from the pit of the New England Brick Company half a mile west of Still River station is mixed with some sand and made by machinery into common pressed brick. A kiln of this brick is said to require about ten days to burn with wood. Similar clay was formerly used at Bailey's brickyard, three-fourths of a mile north of Still River station, on the east side of the valley, and at an early day brick was made on the Burbank place, east of Whittemore Hill, from clay excavated near the edge of the marsh.

Examination of these clays under the microscope shows them to be composed of minute angular fragments of various minerals, principally quartz and feldspar, ranging from a very uniform upper limit of grains one-eighth to one-half millimeter in diameter down to the limit of vision. A sample from the New England Brick Company's clay bank shows the grains to be very uniform in character, but a small percentage being larger than one-seventieth of a millimeter in diameter. Clay taken from the middle of two of the exposures showed the following chemical composition:

Analyses of clays from Worcester County, Mass.

[George Steiger, analyst.]

	1.	2.
SiO_2	66.65	57.88
Al_2O_3	16.93	20.68
Fe_2O_3	3.05	3.94
FeO	.84	2.08
MgO	.96	1.60
CaO	1.07	1.03
Na_2O_3	2.05	1.99
K_2O	3.60	4.74
H_2O-	1.54	1.38
H_2O+	3.03	3.63
TiO_2	.80	.88
CO_2	None.	....
	100.52	99.83

1. Farnsworth pit, northeast of Lancaster. 2. Brickworks west of Still River station.

These clays are well adapted to the manufacture of common brick and, being largely free from pebbles, would probably make earthenware of low grade, such as flowerpots. The high percentages of alkalies and other fluxes, however, render them unsuitable for vitrified products.

SURVEY PUBLICATIONS ON CLAYS, FULLER'S EARTH, ETC.

In addition to the papers named below, some of the publications listed under the heading "Cement" contain references to clays. Certain of the geologic folios also contain references to clays, fuller's earth, etc.

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. Those marked "Exhausted" are not available for distribution, but may be seen at the larger libraries of the country.

ASHLEY, G. H. Notes on clays and shales in central Pennsylvania. In Bulletin 285, pp. 442–444. 1906.

ASHLEY, H. E. The colloid matter of clay and its measurement. Bulletin 388. 65 pp. 1909.

BASTIN, E. S. Clays of the Penobscot Bay region, Maine. In Bulletin 285, pp. 428–431. 1906.

BRANNER, J. C. Bibliography of clays and the ceramic arts. Bulletin 143. 114 pp. 1896. 15c.

——— The clays of Arkansas. Bulletin 351. 247 pp. 1908.

BUTTS, CHARLES. Clays of the Birmingham district, Alabama. In Bulletin 315, pp. 291–295. 1907. 50c.

CRIDER, A. F. Clays of western Kentucky and Tennessee. In Bulletin 285, pp. 417–427. 1906.

DARTON, N. H. Geology and water resources of the northern portion of the Black Hills and adjoining regions in South Dakota and Wyoming. Professional Paper 65. 106 pp. 1909.

DARTON, N. H., and SIEBENTHAL, C. E. Geology and mineral resources of the Laramie Basin, Wyoming; a preliminary report. Bulletin 364. 81 pp. 1909.

ECKEL, E. C. Stoneware and brick clays of western Tennessee and northwestern Mississippi. In Bulletin 213, pp. 382–391. 1903. 25c.

——— Clays of Garland County, Ark. In Bulletin 285, pp. 407–411. 1906.

FENNEMAN, N. M. Clay resources of the St. Louis district, Missouri. In Bulletin 315, pp. 315–321. 1907. 50c.

FISHER, C. A. The bentonite deposits of Wyoming. In Bulletin 260, pp. 559–563. 1905. 40c.

——— Clays in the Kootenai formation near Belt, Mont. In Bulletin 340, pp. 417–423. 1908.

FULLER, M. L. Clays of Cape Cod, Massachusetts. In Bulletin 285, pp. 432–441. 1906.

LANDES, HENRY. The clay deposits of Washington. In Bulletin 260, pp. 550-558. 1905. 40c.

LINES, E. F. Clays and shales of the Clarion quadrangle, Clarion County, Pa. In Bulletin 315, pp. 335-343. 1907. 50c.

MATSON, G. C. Notes on the clays of Florida. In Bulletin 380, pp. 346-356. 1909.

MIDDLETON, JEFFERSON. Clay-working industries. In Mineral Resources U. S. for 1908, pt. 2, pp. 455-504. 1909.[a]

PHALEN, W. C. Clay resources of northeastern Kentucky. In Bulletin 285, pp. 412-416. 1906.

——— Economic geology of the Kenova quadrangle, Kentucky, Ohio, and West Virginia. In Bulletin 349, pp. 112-122. 1908.

PHALEN, W. C., and MARTIN, LAWRENCE. Clays and shales of southwestern Cambria County, Pa. In Bulletin 315, pp. 344-354. 1907. 50c.

PORTER, J. T. Properties and tests of fuller's earth. In Bulletin 315, pp. 268-290. 1907. 50c.

RIES, H. Technology of the clay industry. In Sixteenth Ann. Rept., pt. 4, pp. 523-575. 1895. $1.20.

——— The pottery industry of the United States. In Seventeenth Ann. Rept., pt. 3, pp. 842-880. 1896.

——— The clays of the United States east of the Mississippi River. Professional Paper 11. 298 pp. 1903. 40c.

SCHRADER, F. C., and HAWORTH, E. Clay industries of the Independence quadrangle, Kansas. In Bulletin 260, pp. 546-549. 1905. 40c.

SHALER, M. K., and GARDNER, J. H. Clay deposits of the western part of the Durango-Gallup coal field of Colorado and New Mexico. In Bulletin 315, pp. 296-302. 1907. 50c.

SHALER, N. S., WOODWORTH, J. B., and MARBUT, C. F. The glacial brick clays of Rhode Island and southeastern Massachusetts. In Seventeenth Ann. Rept., pt. 1, pp. 957-1004. 1896.

SIEBENTHAL, C. E. Bentonite of the Laramie Basin, Wyoming. In Bulletin 285, pp. 445-447. 1906.

STOSE, G. W. White clays of South Mountain, Pennsylvania. In Bulletin 315, pp. 322-334. 1907. 50c.

VAN HORN, F. B. Fuller's earth. In Mineral Resources U. S. for 1907, pp. 731-734, pt. 2. 1908. $1.00.

VAUGHAN, T. W. Fuller's earth of southwestern Georgia and Florida. In Mineral Resources U. S. for 1901, pp. 922-934. 1902. 50c.

——— Fuller's earth deposits of Florida and Georgia. In Bulletin 213, pp. 392-399. 1903. 25c.

VEATCH, O. Kaolins and fire clays of central Georgia. In Bulletin 315, pp. 303-314. 1907. 50c.

WOOLSEY, L. H. Clays of the Ohio Valley in Pennsylvania. In Bulletin 225, pp. 463-480. 1904. 35c.

[a] Previous volumes of the Mineral Resources of the United States contain chapters devoted to clay and the clay-working industries of the United States.

GYPSUM AND PLASTERS.

THE GYPSUM DEPOSITS OF THE PALEN MOUNTAINS, RIVERSIDE COUNTY, CALIFORNIA.

By E. C. Harder.

GENERAL STATEMENT.

Extensive deposits of gypsum occur in the Palen Mountains between the Colorado and Mohave deserts, in northern Riverside County, Cal. At present they are of little economic importance, being 50 miles from Parker, Ariz., and 60 miles from Danby, Cal., both on the Atchison, Topeka and Santa Fe Railway, and 70 miles from Mecca, Cal., on the Southern Pacific Railroad. The route from Mecca is the common way of approach. The new cut-off of the Santa Fe from Parker to Cadiz, Cal., now under construction, will, however, probably pass within about 15 miles of the deposits. (See fig. 33.)

The gypsum is very pure, occurring in extensive layers interbedded with limestone in a limestone, gypsum, and quartzite series. Most of it is finely crystalline and compact and varies in color from transparent white to slightly reddish. A small percentage of the material is anhydrite, finely granular and snow-white, occurring in layers and lenses in the crystalline gypsum. Both varieties contain some calcium carbonate, the anhydrite in places as much as 20 per cent. A considerable proportion of the gypsum is sufficiently compact to be used for ornamental purposes.

Some of the gypsum beds reach a thickness of a few hundred feet, with little interbedded limestone; the entire gypsum-bearing series is probably several thousand feet in thickness. In some places the gypsum is predominant, but elsewhere the limestone is by far the more abundant. Several beds of quartzite occur in the series, interlayered with limestone and locally reach a considerable thickness.

The gypsum-bearing belt is roughly about 3 miles long and from half a mile to 1½ miles wide. It runs across the Palen Mountains in a general east-west direction, disappearing under unconsolidated desert deposits on both sides. It is bounded on the north by a great mass of granite and on the south by shales and quartzites with intrusive igneous rocks of several varieties. The gypsum beds are largest and most abundant in the southern part of the belt. The strike of the beds varies between east-west and northeast-southwest; the dip is at varying angles to the north or northwest.

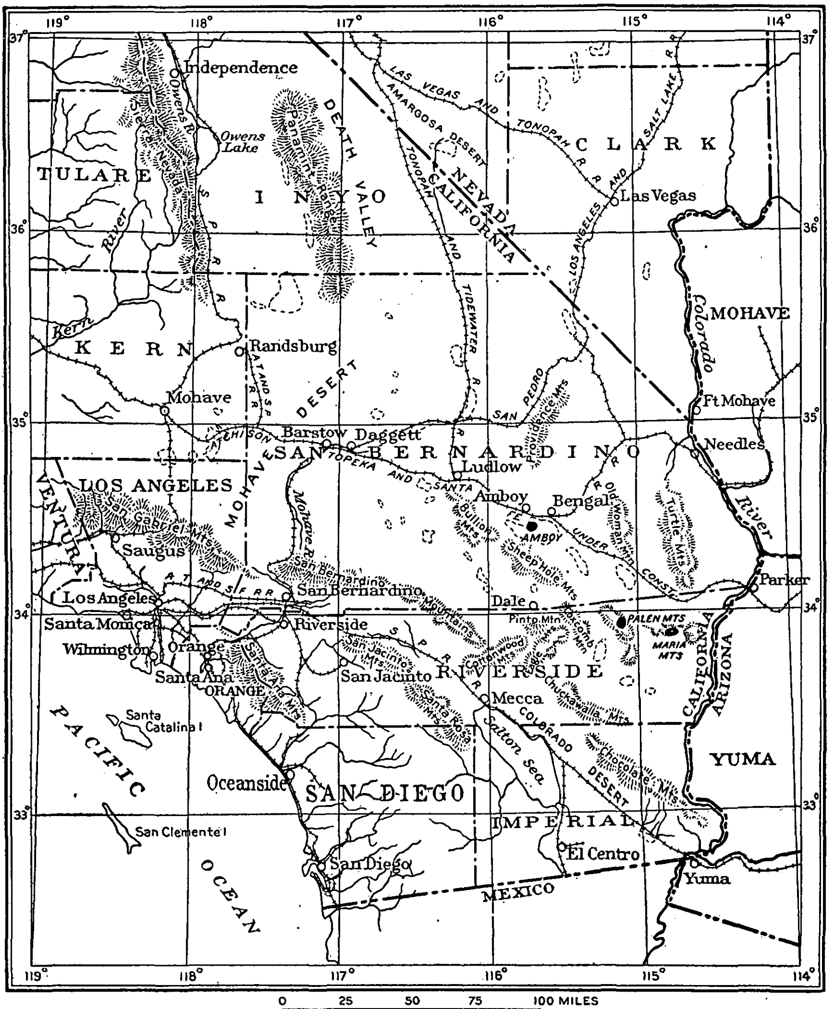

FIGURE 33.—Map showing location of known gypsum deposits in southeastern San Bernardino and Riverside counties, Cal.

A dark intrusive igneous rock occurs within the gypsum-limestone area, being especially abundant in the northern half of the belt. It cuts the gypsum beds more commonly than the limestone and quartzite because of their softer nature. On account of this fact many of the gypsum beds are locally so intricately intermixed with igneous rock as to be almost valueless. However, large portions of the area are free from these intrusive rocks.

The Palen Mountain gypsum beds are practically untouched, except for a few short tunnels that have been driven in here and there to answer the requirements for assessment work.

The gypsum and limestone of the Palen Mountains reappear 5 or 6 miles to the east from under the desert deposits and occur throughout the extent of the Maria Mountains. In the western part of these mountains limestone is predominant, but in the central part gypsum deposits of even greater extent than those in the Palen Mountains are reported to occur.

The age of the gypsum-bearing series is unknown. In general appearance, texture, and metamorphism the rocks resemble other sediments of the southeastern Mohave Desert that have generally been considered of pre-Cambrian age. The sediments of central western Arizona have been shown to be of pre-Cambrian age and to be intruded by Mesozoic granitic and dioritic rocks. Bancroft [a] and Schrader [b] have examined these rocks in Arizona and for a short distance west of Colorado River in California, to a point about 30 miles directly east of the Palen Mountains. It is supposed that they extend westward into the Mohave Desert, but they have not been correlated with the rocks of the Palen Mountains and other areas to the west.

About 50 miles north of the Palen Mountain area, near Siam, on the Santa Fe Railway, Darton [c] has found a series of sediments of Cambrian age and also sediments of probable Carboniferous age. These rocks, however, have apparently suffered no dynamic metamorphism, and in this respect are unlike the sediments of the Palen Mountains. However, the latter may be of Paleozoic age, their metamorphism being due to heat and pressure accompanying the great intrusion of granite to the north.

LOCATION AND TOPOGRAPHY.

The Palen Mountains have a general north-south direction, being about 20 miles long and of varying width. They are slightly crescent-shaped, with the opening to the west. At both ends they are high and rugged, but at the center, where crossed by the Parker-Mecca road, they are low and narrow. The southern portion of the range is much wider than the northern portion. The gypsum deposits occur in the central part of the range, south of the Parker-Mecca road.

The Palen Mountains are surrounded by broad, flat desert areas, beyond which are other mountain ranges. Like most of the ranges

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[a] Bancroft, Howland, Reconnaissance of the ore deposits of central western Arizona: Bull. U. S. Geol. Survey (in preparation).

[b] Schrader, F. C., Mineral deposits of the Cerbat Range, Black Mountains, and Grand Wash Cliffs, Arizona: Bull. U. S. Geol. Survey No. 397, 1909.

[c] Darton, N. H., Discovery of Cambrian rocks in southeastern California: Jour. Geology, vol. 15, 1907, pp. 470-473.

in the Mohave and Colorado deserts, they are bare of trees except along the outwash aprons bordering them, where small stunted growths of ironwood and palo verde occur sparingly. On the mountains themselves only greasewood, cacti, and a few varieties of sagebrush grow.

The only watering place in the district, with the exception of a few natural tanks along some of the canyons, is Packard's well, located in the pass near the road. Boulder well is 20 miles to the southwest, in the middle of a broad desert, and Brown's well is about 20 miles to the east. Packard's well is open, and consequently the water generally contains numerous dead bees and desert animals, which make it unfit to drink except for stock.

GENERAL GEOLOGY.

North of the gypsum-bearing series and presumably composing most of the northern half of the range is a coarsely crystalline porphyritic biotite granite, with phenocrysts of pink orthoclase. Biotite is very abundant, giving to the rock a grayish-pink color. Dikes of medium-grained pink granite or aplite cut the coarse porphyritic granite abundantly in all directions. These dikes consist largely of quartz and pink feldspar, with minor quantities of muscovite and biotite.

South of the granite mass is a belt from a quarter to half a mile wide, of low rolling hills made up of unconsolidated gravel, sand, and bowlders and extending in an east-west direction across the range.

The sedimentary rocks, consisting of limestone, gypsum, sandstone, quartzite, shale, and slate, lie south of this low belt and dip at varying angles to the north or northwest. Intrusive rocks of several varieties cut them in many places. The sediments and intrusive rocks are arranged roughly in bands trending a little south of west, with the following general succession from northwest to southeast: (1) Limestone with little interbedded gypsum, found only in the northwestern part of the area; (2) intrusive quartz-biotite diorite extending about two-thirds of the way across the range from west to east; (3) interbedded limestone and gypsum, with quartzite, fine-grained sandstone, and chert in the lower (southeastern) part. This band extends entirely across the range. The limestone and gypsum are well developed in the northeastern part, but in the southwestern part are almost entirely replaced by the quartzite, sandstone, and chert; (4) intrusive quartz-biotite diorite which is well developed in the northeastern and central parts, but gradually pinches out at the southwest end; (5) interbedded gypsum and limestone, the former the more abundant. This is the widest of the five belts and also extends entirely across the range from desert to desert. Gypsum is very abundant in its southwestern and central portions, but gives place to limestone toward the northeast; (6) interbedded green sandstones, quartzites, conglomerates, and shales. This series is wide in the southwestern part, but is cut off entirely near the northeast end by (7) a dark-gray intrusive quartz porphyry. The extent of the quartz porphyry to the south is not known, but it is presumably not great, and beyond the porphyry there may be more quartzites and slates cut by other intrusive rocks. Such a complex probably forms the southern half of the mountains, but no more limestone or gypsum occurs south of the mass of quartz porphyry. As the entire limestone-gypsum belt is only from half a mile to 1½ miles wide, it occupies but a small portion of the Palen Mountains.

The limestones are white to light brown or grayish brown in color and vary in texture from coarsely crystalline to massive and granular. Gypsum is interlayered with them, sparingly in the northern area, more abundantly in the central area, and predominantly in the southern area. The gypsum beds reach a thickness of several hundred feet, but the limestone beds, especially in the northern area, are much thicker. Between the large gypsum and limestone beds there is generally a transition zone several feet in thickness of interlayered limestone, gypsum, and anhydrite. The gypsum and anhydrite in this zone are strongly impregnated with calcium carbonate.

The northern area is predominantly limestone, with no quartzite and but few intrusive masses. Gypsum occurs in it in thin, scattered lenses of little or no importance.

The central limestone-gypsum area contains in its northern and eastern parts limestone and gypsum in about equal abundance, but in its southern and western parts it is occupied almost entirely by fine-grained quartzite and a series of interlaminated chert and limestone layers that form a row of sharp, steep-sided peaks trending northeast and southwest. The dip of the beds taken at various points along this band showed a variation between 25° and 50° NE.; the strike varies from N. 55° E. to east-west.

Intrusive sheets or irregular masses of quartz-mica diorite occur abundantly in all the rocks, and locally contact minerals are developed, especially near the contact with limestone or laminated limestone and chert strata. The metamorphic minerals are mostly garnet, epidote, hornblende, and quartz. Small deposits of iron ore, consisting of magnetite, hematite, and limonite intermixed, occur in several places at the limestone and diorite or quartzite and diorite contacts. At some places serpentine is present in small quantities in the limestone, and locally it is concentrated along the diorite contact in association with the iron ore. Tremolite, chlorite (penninite), selenite, dolomite, calcite, pyrite, and copper sulphides also occur with the iron-ore masses, but they contain no garnet or epidote. Small veins of green asbestos are found in the serpentine along the diorite contact, and bunches of soft white asbestos are associated with serpentine locally along the contact of limestone and gypsum beds. The intrusive bodies of diorite in the gypsum vary from large irregular masses to small ramifying dikes less than an inch in thickness; those in the other formations are generally massive and regular. The gypsum has been intruded abundantly by networks of dikes because of its easy access. Apparently the intrusions have had little or no effect on the gypsum at the contact except local pulverizing and probably dehydration.

The southern limestone-gypsum belt is occupied largely by gypsum in the southwestern and central parts but contains much limestone in the northeastern part. The limestone layers, being harder than the gypsum, stand above it in ridges and peaks, whereas the gypsum forms smooth, gradual slopes. A lens of quartzite divides the limestone-gypsum belt into two portions in the eastern part of the area. Small intrusions of diorite occur locally, though they are much less abundant than in the central belt. The dip of the beds averages about 40° NW.; the strike varies between N. 65° E. and N. 80° E.

The quartz-biotite diorite is intrusive into the gypsum-bearing series, occurring chiefly in the two large areas which separate the central limestone-gypsum belt from the northern and southern belts, but also as small scattered masses within the central and southern areas and in the shale beds to the south. The rock varies much in texture and general appearance in the different areas and in different parts of the same area. However, one phase grades into another and the mineral constituents are much the same throughout.

The minerals composing the diorite are largely plagioclase feldspar, quartz, and biotite. In some places the biotite is very abundant and the rock is dark and rather schistose; elsewhere the feldspar and quartz predominate, making the rock light colored and foliated rather than schistose. The rock is fine grained, containing small phenocrysts of feldspar sparingly in some places and abundantly in others. In the light-colored phases fine flakes of biotite are in places segregated into bunches arranged along definite lines, thus producing the foliation. Locally areas of biotite diorite are strongly epidotized and contain numerous veins of epidote. Some small masses consist entirely of hornblende and epidote. Quartz veins are characteristic of all the intrusive masses. Some of them are clean cut; others occur as large irregular masses in brecciated zones. Copper sulphides and stains of copper carbonate are found in many of these veins.

The shales, quartzites, and slates bounding the limestone-gypsum area on the south are of a prevailing green color. They are compact and fine grained for the most part, but are interlayered with extensive beds of conglomerate. The succession southward from the limestone-gypsum belt is: (1) A great thickness of green and gray shales and slates, intruded by black schistose quartz-biotite diorite; (2) fine-grained green quartzite and conglomerate.

The quartz porphyry is intruded into these rocks at an angle to the bedding, so that toward the northeast it cuts out the quartzite and conglomerate beds and then the shale and slate beds, coming directly into contact with the limestone in the eastern part of the area. The quartz porphyry is a dense, compact rock with a dark-gray fine-grained groundmass in which are scattered phenocrysts of fresh, glassy quartz and feldspar.

STRUCTURE AND ORIGIN OF THE GYPSUM BEDS.

Gypsum deposits have been divided by Hess[a] into four main types—(1) efflorescent deposits, (2) periodic-lake deposits, (3) interbedded deposits, and (4) veins.

Efflorescent deposits are formed by the evaporation of water that has percolated through gypsiferous sandstones and shales. These are surface deposits and most of them lie on the tops of hills and ridges. They are thin and rather narrow, though some of them are 10 or 15 feet thick and have an area of several acres. This gypsum is of the variety gypsite. It is buff to creamy or rust colored, soft, and easily crumbled in the hands. Some of it is powdery and resembles ashes, though under the microscope all of it is seen to consist of small crystalline scales.

Periodic-lake deposits are formed by the crystallization of gypsum from the saturated waters of intermittent shallow lakes. They occur as beds in alkali or dry lake flats and are in many places covered by several feet of soil. The gypsum is generally granular and crystalline, the particles ranging in size from minute specks to scales a quarter of an inch in breadth.

Interbedded deposits are of two principal varieties, one consisting of thin beds of impure gypsum from a fraction of an inch to 3 or 4 inches thick, interstratified with clayey material, and the other of beds of pure gypsum ranging up to many feet in thickness, interlayered with limestone or other sediments. The deposits of the first variety were probably formed by precipitation in a shallow sea into which large quantities of sediments were being poured; those of the second were laid down in deep water under more constant conditions of saturation.

Gypsum veins consist of the transparent crystalline variety of gypsum known as selenite, or in a few places of the columnar variety known as satin spar. They are formed by the solution of gypsum

[a] Hess, F. L., A reconnaissance of the gypsum deposits of California: Bull. U. S. Geol. Survey No. 413, 1910, pp. 7-8.

from the surrounding rocks or from other deposits and its redeposition in cracks.

The Palen Mountain gypsum beds belong to the second variety of interbedded deposits. In detail they consist largely of finely crystalline selenite in flakes varying up to one-tenth of an inch or more in diameter. The individual flakes are transparent and colorless, but in aggregates they are white or slightly cream-colored. At a few localities the gypsum has a beautiful orange-red tint.

Interlayered with the crystalline gypsum, but much less abundant and apparently only local in its occurrence, is a finely granular snow-white mixture of anhydrite and calcium carbonate. It is found in lenses varying up to several feet in diameter within the selenite and also in the transition zones between large limestone and gypsum beds. The contact between the granular and the crystalline material is generally sharp. However, small bunches of selenite are scattered through the anhydrite lenses and small bunches of anhydrite occur in the selenite beds. The contact of the larger gypsum and limestone beds is generally marked by a transitional zone, consisting of interlayered calcium sulphate and limestone. The calcium sulphate in this zone is largely anhydrite and has considerable calcium carbonate intermixed with it, and the limestone probably contains some calcium sulphate. Layers of limestone, varying down to less than half an inch in thickness, occur in the anhydrite near the base or top of the larger gypsum beds, and similarly thin layers of anhydrite occur in limestone near the borders of the main limestone layers. The contact between these thin layers and the inclosing rock is everywhere sharp, showing a succession of changes in deposition. Such transition zones between the main beds are locally 6 feet or more in thickness.

In some places gypsum beds of great thickness occur with little or no interbedded limestone; in others there are great thicknesses of limestone without gypsum. Commonly, however, the deposits alternate in layers varying from less than a foot to 40 or 50 feet in thickness. In some places thin beds of limestone occur between thick gypsum beds; elsewhere thin beds of gypsum are found between heavy beds of limestone.

Most of the crystalline gypsum contains a small percentage of calcium carbonate and the granular mixture of anhydrite and calcium carbonate may contain as high as 20 per cent of it. As the granular material, however, makes up but a small proportion of the beds, by far the larger part of the gypsum is fairly pure. The following partial chemical analyses represent picked samples of the crystalline gypsum and the granular mixture of anhydrite and calcium carbonate:

Chemical analyses of gypsum and of anhydrite and calcium carbonate from the Palen Mountains.

[George Steiger, analyst.]

	Crystalline gypsum.	Anhydrite and calcium carbonate.
CaO	32.55	37.13
H_2O-	.03	.04
H_2O+	18.23	1.27
CO_2	6.03	17.57
SO_3	41.47	37.15
	98.31	93.16
Undetermined (MgO, Cl., etc.)	1.69	6.84

The mineral composition of the gypsum and anhydrite, calculated from the preceding chemical analyses, is as follows:

Mineral composition of gypsum and of anhydrite and calcium carbonate from the Palen Mountains.

	Crystalline gypsum.	Anhydrite and calcium carbonate.
Gypsum	87.31	6.27
Anhydrite	1.31	58.21
Calcite	6.53	19.84
Surplus CO_2	3.16	8.84
	98.31	93.16
Undetermined	1.69	6.84

In making these calculations all the H_2O present is assumed to be combined with the requisite quantities of CaO and SO_3 to form gypsum. Water of combination and uncombined water are added together, because it is difficult to distinguish between them in gypsum analyses. The surplus SO_3 is then combined with the CaO necessary to form anhydrite, after which the surplus CaO is combined with enough CO_2 to form calcite. The CO_2 remaining after these calculations may be assumed to be combined with the undetermined constituents in the form of carbonates. In both analyses, however, even if the most favorable condition is assumed, namely, that all the undetermined material is MgO, there is still some surplus CO_2 after the formation of $MgCO_3$. This fact shows that besides the calcium sulphates other sulphates must be present in which the proportion of SO_3 to the base is greater than in the calcium sulphates, thus leaving a greater proportion of CaO and other bases for combination with the surplus CO_2. It is also possible that not all the H_2O is combined in the form of gypsum and that there are compounds of intermediate hydration between gypsum and anhydrite in which the proportion of SO_3 to CaO is greater than in gypsum. Some chlorides are also undoubtedly present.

From the occurrence of the gypsum in beds alternating with layers of limestone there seems little doubt that it was formed as an original deposit from supersaturated waters. The formation of the white granular mixture of anhydrite and calcium carbonate that occurs in lenses within the selenite beds and at their contact with the limestone is due to an original difference in composition. The occurrence of this mixture in the contact zone between the limestone and gypsum beds shows a gradual transition from the deposition of one to that of the other. After the consolidation of the beds regional folding and metamorphism took place, altering the limestone locally to a coarse marble and the gypsum widely to selenite. Later occurred the intrusion of the diorite, which broke through the selenite in many places, partly dehydrated it here and there along the contacts, and changed it from crystalline rock to a friable white powder.

GYPSUM DEPOSITS NEAR CANE SPRINGS, KERN COUNTY, CALIFORNIA.

By Frank L. Hess.

About 3½ miles southeast of Cane Springs, Cal., on the new line of the Southern Pacific Railroad joining Mohave and Keeler, gypsite deposits of some extent were discovered in the fall of 1909. The area is in the Mohave Desert, about 30 miles northeast of Mohave, in a fault valley of a type common to the desert. This valley has no outlet and receives the water of the intermittent streams that flow from the surrounding mountains and form a periodic lake or playa. No perennial streams discharge into the basin, but at times heavy storms cause the intermittent streams to flow so that the lake bed is covered to a depth of 1 or 2 feet. The valley is probably 7 or 8 miles wide and 25 miles long.

On the south and east the valley is bordered by old crystalline rocks, granites, and schists. On the north and west lie the Nugget and El Paso mountains, which are composed of old crystalline and effusive rocks, Tertiary sandstones, and older sedimentary strata, including both limestone and fragmental rocks. No rocks in place are exposed in the valley except at the edge of the débris on either side. The valley is deeply filled with detritus, which is shown by borings to be more than 800 feet deep and is finer toward the center of the valley. The lake bed, about 5 by 8 miles in extent, is covered with a fine mud. On the northeast side of the lake the valley floor consists of sand, but on the southwest it is made up of silt similar to that of the lake bed. It is probable that the land on the south was once covered by the lake and that the lake's position has been moved owing to the unequal lowering of the present bed by faulting.

The gypsite deposits, so far as known, are located on the south edge of the present playa, in what was possibly its former bed, on a slope which rises gently to the southwest. The gypsite is exceedingly fine grained, of a buff color, and is exposed at the surface over an area covering nearly a section. A grass called saccaton grows over the entire area and its roots sink into the gypsite. The thickest beds lie in the SE. ¼ NW. ¼ sec. 28, T. 30 S., R. 38 E., Mount Diablo base and meridian, and reach a depth of 10 feet, occupying the higher ground between the shallow stream beds leading to the lake. In places the streams have dissolved the gypsite and left small sinks similar to those in a limestone country. In the lower places the gypsite is thin, at many points being not more than 1 or 2 feet thick. Here and there the gypsite is somewhat mixed with clay; in other places the clay has flowed over the gypsite at times of high water, and this process has been repeated, so that several layers of clay are intercalated with the gypsite.

There is an efflorescence of sodium carbonate and sodium sulphate on the surface, but it forms no considerable impurity in the gypsite.

The gypsite becomes thinner and gives out entirely where the damp earth of the lake bed is reached, so far as present exploitation shows. The ground beneath the gypsite is apparently made up of alternating beds of clays, sands, and gravels, and the gypsite is probably formed by efflorescence from these materials.

A partial analysis of a specimen collected where prospect holes showed the gypsum to be thickest is as follows:

Partial analysis of gypsite from the deposit 3½ miles southeast of Cane Springs, Kern County, Cal.

[George Steiger, analyst.]

Lime (CaO)	28.76
Sulphur trioxide (SO_3)	37.06
Carbon dioxide (CO_2)	1.87
Water driven off at 60° C.	.78
Water driven off at 300° C.	17.30
Chlorine (Cl)	Trace.
Iron oxide (Fe_2O_3)	.71

This shows an equivalent of about 79.5 per cent of gypsum. The most striking item in the analysis is an excess of water, which is probably present in clay. Some lime carbonate is present. The iron is low. Salt had been reported as present, but in the sample collected there was too small a quantity to weigh. There seem to be no elements present which would be detrimental in the manufacture of plaster. The clay would probably make it leave the trowel better than if it were not present.

On the north side of the gypsite deposits is an artesian well with a small flow of very good water. The depth of the well was not learned but is supposed to be more than 100 feet. The water is slightly impregnated with hydrogen sulphide (H_2S), which may possibly come from the alteration of gypsum.

SURVEY PUBLICATIONS ON GYPSUM AND PLASTERS.

The more important publications of the United States Geological Survey on gypsum and plasters are included in the following list. 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.

ADAMS, G. I., and others. Gypsum deposits of the United States. Bulletin 223. 123 pp. 1904. 25c.

BOUTWELL, J. M. Rock gypsum at Nephi, Utah. In Bulletin 225, pp. 483–487. 1904. 35c.

BURCHARD, E. F. Gypsum and gypsum products. In Mineral Resources U. S. for 1908, pt. 2, pp. 621–627. 1909.

DARTON, N. H., and SIEBENTHAL, C. E. Geology and mineral resources of the Laramie Basin, Wyoming; a preliminary report. Bulletin 364. 81 pp. 1909.

ECKEL, E. C. Gypsum and gypsum products. In Mineral Resources U. S. for 1905, pp. 1105–1115. 1906. $1.

HESS, F. L. A reconnaissance of the gypsum deposits of California. Bulletin 413. 37 pp. 1910.

RICHARDSON, G. B. Salt, gypsum, and petroleum in trans-Pecos Texas. In Bulletin 260, pp. 573–585. 1905. 40c.

SHALER, M. K. Gypsum in northwestern New Mexico. In Bulletin 315, pp. 260–265. 1907. 50c.

SIEBENTHAL, C. E. Gypsum of the Uncompahgre region, Colorado. In Bulletin 285, pp. 401–403. 1906. 60c.

——— Gypsum deposits of the Laramie district, Wyoming. In Bulletin 285, pp. 404–405. 1906. 60c.

LIME AND MAGNESITE.

SURVEY PUBLICATIONS ON LIME AND MAGNESITE.

In addition to the papers listed below, which deal principally with lime, magnesite, etc., further references on limestones will be found in the lists given under the heads "Cement" and "Building stone." These publications, except the one to which a price is affixed, can be obtained free by applying to the Director, United States Geological Survey, Washington, D. C. The priced publication may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.

BASTIN, E. S. The lime industry of Knox County, Me. In Bulletin 285, pp. 393–400. 1906. 60c.

BURCHARD, E. F., BUTTS, CHARLES, and ECKEL, E. C. Iron ores, fuels, and fluxes of the Birmingham district, Alabama. Bulletin 400. 204 pp. 1910.

BUTTS, CHARLES. Limestone and dolomite in the Birmingham district, Alabama. In Bulletin 315, pp. 247–255. 1907.

CALKINS, F. C., and MACDONALD, D. F. A geologic reconnaissance in northern Idaho and northwestern Montana. Bulletin 384. 112 pp. 1909.

COONS, A. T. Lime. In Mineral Resources U. S. for 1908, pt. 2, pp. 511–515. 1909.

HESS, F. L. Some magnesite deposits of California. In Bulletin 285, pp. 385–392. 1906. 60c.

——— The magnesite deposits of California. Bulletin 355. 67 pp. 1908.

RIES, H. The limestone quarries of eastern New York, western Vermont, Massachusetts, and Connecticut. In Seventeenth Ann. Rept., pt. 3, pp. 795–811. 1896.

YALE, C. G. Magnesite. In Mineral Resources U. S. for 1908, pt. 2, pp. 739–741, 1909.

GLASS SAND, ETC.

SURVEY PUBLICATIONS ON GLASS SAND AND GLASS-MAKING MATERIALS.

The list below includes the important publications of the United States Geological Survey on glass sand and glass-making materials. 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.

BURCHARD, E. F. Requirements of sand and limestone for glass making. In Bulletin 285, pp. 452–458. 1906.

——— Glass sand of the middle Mississippi basin. In Bulletin 285, pp. 459–472. 1906.

——— Glass-sand industry of Indiana, Kentucky, and Ohio. In Bulletin 315, pp. 361–376. 1907.

——— Notes on glass sands from various localities, mainly undeveloped. In Bulletin 315, pp. 377–382. 1907.

FENNEMAN, N. M. Geology and mineral resources of the St. Louis quadrangle. Bulletin 438 (in preparation).

STOSE, G. W. Glass-sand industry in eastern West Virginia. In Bulletin 285, pp. 473–475. 1906.

WEEKS, J. D. Glass materials. In Mineral Resources U. S. for 1883–1884, pp. 958–973. 1885. 60c.

——— Glass materials. In Mineral Resources U. S. for 1885, pp. 544–555. 1886. 40c.

ABRASIVES.

SURVEY PUBLICATIONS ON ABRASIVE MATERIALS.

The following list includes a number of papers, published by the United States Geological Survey or by members of its staff, dealing with various abrasive materials. The government 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 one marked "Exhausted" is not available for distribution, but may be seen at the larger libraries of the country.

ARNOLD, RALPH, and ANDERSON, ROBERT. Diatomaceous deposits of northern Santa Barbara County, Cal. In Bulletin 315, pp. 438–447. 1907. 50c.

CHATARD, T. M. Corundum and emery. In Mineral Resources U. S. for 1883–84, pp. 714–720. 1885. 60c.

ECKEL, E. C. The emery deposits of Westchester County, N. Y. In Mineral Industry, vol. 9, pp. 15–17. 1901.

HOLMES, J. A. Corundum deposits of the southern Appalachian region. In Seventeenth Ann. Rept., pt. 3, pp. 935–943. 1896.

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PARKER, E. W. Abrasive materials. In Nineteenth Ann. Rept., pt. 6, pp. 515–533. 1898.

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PRATT, J. H. The occurrence and distribution of corundum in the United States. Bulletin 180. 98 pp. 1901. 20c.

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RABORG, W. A. Buhrstones. In Mineral Resources U. S. for 1886, pp. 581–582. 1887. 50c.

——— Grindstones. In Mineral Resources U. S. for 1886, pp. 582–585. 1887. 50c.

——— Corundum. In Mineral Resourses U. S. for 1886, pp. 585–586. 1887. 50c.

READ, M. C. Berea grit. In Mineral Resources U. S. for 1882, pp. 478–479. 1883. 50c.

SIEBENTHAL, C. E., and MESLER, R. D. Tripoli deposits near Seneca, Mo. In Bulletin 340, pp. 429–437. 1908.

TURNER, G. M. Novaculite. In Mineral Resources U. S. for 1885, pp. 433–436. 1886. 40c.

——— Novaculites and other whetstones. In Mineral Resources U. S. for 1886, pp. 589–594. 1887. 50c.

WOOLSEY, L. H. Volcanic ash near Durango, Colo. In Bulletin 285, pp. 476–479. 1906. 60c.