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JOHN M. CLARKE, Director

THE QUARRY MATERIALS OF NEW YORK—GRANITE, GNEISS, TRAP AND MARBLE

BY

D. H. NEWLAND

PAGE

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SIR: I have the honor to transmit to you herewith and to recommend for publication as a bulletin of the State Museum, a manuscript and illustrations of a report on *The Quarry Materials of New York — Granite, Gneiss, Trap and Marble,* by David H. Newland, Assistant State Geologist.

Very respectfully

JOHN M. CLARKE

Director

Approved for publication this 15th day of March 1915

President of the University

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JOHN M. CLARKE, Director

THE QUARRY MATERIALS OF NEW YORK—GRANITE, GNEISS, TRAP AND MARBLE

BY

D. H. NEWLAND

INTRODUCTION

This report is the partial fulfilment of a plan to describe the quarry resources of the State from the present-day standpoint. It was the original purpose to include in the report a description of the sandstone and limestone quarries as well as those of the crystalline rocks. The task of collecting the information for a complete report, however, would have involved a considerable delay in the publication of the results of the first part of the investigation, which covers the crystalline areas of the Adirondacks and southeastern New York, and it was thought advisable to issue that part separately. It is the hope of the writer that a second report on the stratified rocks may be prepared within a reasonable time.

The division of the subject into two sections as outlined follows a natural line of demarcation in the geographical distribution of the formations; it likewise has a basis in scientific and economic considerations so apparent as to need no emphasis in this place.

The only description of the building stones of New York at all complete that has been available hitherto is found in the two bulletins by John C. Smock. The earlier[1] of these (1888) was of preliminary character, mainly devoted to the description of individual quarries. The second,[2] published in 1890, included most

[1] N. Y. State Mus. Bul. 3, Albany, 1888.

[2] N. Y. State Mus. Bul. 10, Albany, 1890.

of the descriptive matter of the earlier report but also contained chapters on the use of stone in cities, on the durability of stone, and the physical and chemical testing of stone; it was one of the first important quarry reports in this country to treat the subject from the scientific standpoint. The physical determinations as carried out for the report have little practical application at present, as the theory and technic of laboratory tests have been almost revolutionized in the last few years. Naturally, there have also been great changes in the economic situation of the local industry.

Reports of more restricted compass have been issued at different times. A brief account of the New York State quarry industry was given in the volumes of the Tenth Census.[1] A paper on the quarries of southeastern New York, of descriptive character, by E. C. Eckel,[2] was published in the report of the State Geologist for 1900. The limestones were described rather fully in 1901 by H. Ries,[3] and the bluestone industry by H. T. Dickinson in 1903.[4]

With few exceptions, all the quarry localities described in this bulletin have been personally visited, the field work occupying parts of the summers of 1912 and 1913. The samples obtained in the field have been used for optical, physical and chemical investigations in accordance with recent practice in the testing of quarry stones.

The writer has received valuable assistance in both the field and laboratory from R. W. Jones of the Museum staff, who is responsible for much of the chemical work undertaken for the report, and from H. Mattimore of the bureau of research, State Department of Highways, who carried out physical tests on many samples of granites. To them and also to the individual quarry operators who have extended numerous courtesies, the writer desires to express his obligations.

THE DEVELOPMENT OF THE QUARRY INDUSTRY IN NEW YORK

The extraction of stone for building and other purposes in this State has gained prominence as an industry only within relatively recent years. The use of stone in structures, however, goes back to the colonial period. As the most available of the permanent structural materials, it was employed by the early settlers in walls,

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[1] V. 10, Washington, 1884.

[2] Albany, 1902. Also printed separately.

[3] N. Y. State Mus. Bul. 44, Albany, 1901.

[4] N. Y. State Mus. Bul. 61, Albany, 1903.

foundations and occasionally for entire buildings, and there still exist good examples of such work in many of the older communities where they have stood for two centuries and more.

The stone for the early masonry was seldom quarried from solid ledges. Very little of it was cut or otherwise prepared, but it was mostly laid as rubblework. Field stones were the kind mainly used, as they were nearly everywhere abundant and the cheapest to secure, and their removal from the land was desirable from an agricultural standpoint. These stones, it may be remarked, are not indigenous to the locality of their occurrence, but with the soil in which they are found were transported from a more northerly latitude in the sweep of the Laurentian ice sheet that finally extended over the whole State. The bowlders consist of granite, gneiss, sandstone and other rocks hard enough to resist the erosion of ice and water, and of a durability tested by thousands of years exposure to the weather.

There seems no certainty as to the place or time of the first regular quarry operations. Very likely the earliest work was somewhere in the Hudson valley section, and the quarrying of limestone for the manufacture of lime suggests itself as the object of the first steady production of stone. Limestone was also required for the making of iron which was established on a permanent basis in New York State about 1751, when the Sterling furnace in Orange county was built. At the beginning of the last century the manufacture of lime had become an important industry in the Hudson River valley. About 1820 the manufacture of natural cement was started in Ulster and Onondaga counties, the basis of the industry being an impure limestone which by calcination and grinding makes a high-grade hydraulic cement. From the beginning New York State held a prominent place in the cement industry; by 1840 Ulster county alone was producing at the rate of 600,000 barrels a year, according to Mather. The output of natural cement increased to over 4,000,000 barrels a year, but about the year 1900 it began to decline owing to the cheapening of the cost of Portland cement.

The construction of the Erie canal gave an impetus to the quarrying of stone, since considerable quantities of dimension stone were used in the canal locks. It also afforded means for the conveyance of stone from the central and western parts of the State to the more thickly settled region in the east. Thus the Medina and Onondaga building stones were made available. By 1840 there had developed a considerable trade in flagstone which was obtained from the same regions as now, that is, from Ulster, Sullivan, Delaware and Greene counties, and was shipped to New York and other cities along the coast. The annual product at that time is given by Mather as 3,500,000 square feet.

The stone industry of the State was first made the subject of detailed investigation in the work of the Tenth Census of 1880. The information gathered by the census included notes on the occurrence of building stone in the State and statistics of the capital investment represented in the quarries, the number of employees and production. At that time New York ranked sixth among the states in size of its quarry industry, with an output valued at $1,261,495. The industry had then reached its present stage of development so far as variety of products is concerned, but was destined to great changes in technic and to a great increase of production.

The growth of the quarry industry was particularly rapid in the decade from 1890 to 1900. This was a period of remarkable advancement in all kinds of engineering work and manufacturing, in which New York participated to its full share. The metallurgical and chemical uses of limestone showed great increase and continued to grow in the subsequent years. By the year 1900 the annual product of the State had reached a value of $4,039,102 as shown in the reports of the United States Geological Survey. This gave New York third place in the list, next after Vermont, Pennsylvania, as now, holding first rank.

In the year 1913, the latest for which statistics are available, the production was valued at $6,763,054, the valuation being placed on the materials at the quarry and not including slate or stone used in cement manufacture. The figures for the different products and kinds of stone, as returned to the State Geological Survey, are as follows:

Production of stone in New York in 1913

VARIETY	BUILDING STONE	MONUMENTAL	CURBING AND FLAGGING	CRUSHED STONE	ALL OTHER	TOTAL VALUE
Granite	$45 911	$17 013	....	$236 650	$36 068	$335 642
Limestone	101 198	....	$6 546	2 386 632	1 358 302	3 852 678
Marble	127 556	81 330	....	....	43 406	252 292
Sandstone	285 645	....	682 984	46 267	306 376	1 321 272
Trap	....	....	....	1 001 170	....	1 001 170
Total	$560 310	$98 343	$689 530	$3 670 719	$1 744 152	$6 763 054

A review of the industry for the last few years shows that progress has been rapid in some branches, while others have fairly held their own, and that one or two branches have actually declined. The trade in bluestone within the last seven or eight years has fallen off about 50 per cent, owing to the increasing use of cement in street work. The artificial structural materials — stucco, concrete and terra cotta — also have affected adversely the market for building stone by which all quarries have been more or less affected. It is impossible of course to predict whether the present popularity of these materials will continue but it is not likely that they will make such great inroads upon the market for stone in the future as in the past. The use of cement has had one compensating feature in that it has made a large demand for crushed stone though this represents a much lower grade of product than building stone.

The quarries of limestone at present contribute more than one-half of the total value of the stone products of the State, a ratio which holds also in the country generally. It is the kind most commonly marketed for crushed stone, and is also extensively employed in metallurgy and chemical manufactures.

Section 1

GENERAL FEATURES OF ROCKS AND THEIR COMMERCIAL ADAPTABILITY

THE ORIGIN AND CLASSIFICATION OF ROCKS

Rocks may be defined in simplest terms as mineral aggregates. To this definition there may be added also the quality of solidity, an inseparable characteristic perhaps in the popular mind, though not essential from the standpoint of the geologist. These aggregates are made up of a variety of minerals, either singly or in mechanical mixture. They also differ among themselves in their structural features, in the manner in which the minerals are assembled and held together, that is, their textures, and of course according to origin.

The consideration of origin is the most important for the classification of rocks in the first instance. On that basis they may all be divided into two general groups: (1) the igneous rocks, which include all that have consolidated from a molten state and (2) the sedimentary rocks, inclusive of all that have been deposited by water, either in a state of suspension (mechanical action) or solution (chemical action). To the latter may be added also the small class of wind-laid or eolian deposits which are closely allied with the mechanical sediments in their structure and features of occurrence.

To these groups which embrace all rocks from the standpoint of origin, it is customary to add a third group of coordinate rank in the classification, or (3) the metamorphic rocks. This group includes those members of either igneous or sedimentary derivation that have undergone great changes which involve a physical rearrangement and also at times a chemical transformation of the components with the development of a new set of minerals.

There is naturally no sharp line of division between the metamorphic and the other groups; on the other hand, the process of change may be followed in many cases through all the stages from the one to the other, as from an unaltered sediment like clay through shale and slate to hard and thoroughly crystallized schist or gneiss. It is the general practice, however, to place only the more completely changed types in the metamorphic class, and especially those whose origin may not readily be discovered.

The igneous and metamorphic rocks are distinguished from the sedimentary by their crystalline character, the minerals of both having crystallized within the mass. The two are closely associated in areal distribution and together make up the oldest land surfaces now exposed to view. The great Adirondack highland consists entirely of their representatives, all antedating the earliest of the sedimentary rocks that lie upon its border and that in fact have been derived from the disintegration and erosion of the crystallines.

The structure and appearance of the different groups are conditioned by the agencies which have operated in their formation. These features can be best explained, therefore, in the light of the physical and chemical processes now effective within the earth and that have been in force probably since primitive geological times. The general scientific conception of the earth is that of a cooling body, with the interior in a highly heated state, sufficiently hot to produce instant fusion on release of the load of overlying rocks. If the earth was once thoroughly molten, as is postulated by most geologists, then the cooling process must have led to the formation of an igneous crust in the first instance. This primitive crust, through the attack of waters which settled upon it and the decomposing effects of the gases of the atmosphere, afforded the source of the earliest sediments, which were deposited in the depressed portions occupied by the seas. There are no known representatives at present of these earliest igneous and sedimentary formations.

The conditions of cooling, however, must produce a continuous source of strain within the earth in the effort of the outer portion to adjust itself to the still shrinking interior. The periodic release of this strain is evidenced in the production of faults and folds within the crust, affording the relief of pressure necessary for the liquefaction of the potentially molten rock in the interior and its migration toward the surface. Igneous activity, consequently, has not died out, but is still manifest in volcanoes and may be in progress in the hidden depths through the slow movement of large bodies that never reach the surface.

It is also believed that crustal adjustments take place in consequence of the shifting of load upon the the superstructure through the work of rivers. The large rivers bear immense amounts of detritus to be deposited in the seas hundreds and even thousands of miles from the sources. The continental interiors are being worn down and the coastal plains built up in this way. The change of load, it is thought, is compensated by a transfer of material in the substratum in the opposite direction, which causes a sinking of the overweighted part and a corresponding elevation of the lighter areas.

The adjustments, however occasioned, are accompanied by important results in regard to rocks. Near the surface these yield to the strain by fracture, which may take the form of innumerable division planes or joints that break up the masses into polygonal blocks. Or again, there may be formed one or more great fractures along which the rocks have undergone appreciable differential movement with the production of crushed zones. These movements, if sudden, are accompanied by earthquakes. The large fractures may extend downwards for indefinite distances, affording ready channels for the passage of igneous material toward the surface, and thus are connected with volcanic action. They are frequently found with a filling of some igneous rock like trap or porphyry, marking the site of former eruptions.

Within the depths of the earth a point may be reached where the rocks can not accommodate themselves by fracture under the stress of cubical compression, but adjust themselves by plastic yielding or flowage. The weight of the overlying load causes them to have a certain mobility, although actually in a solid state. Under unequal stress as developed by side thrusts, they tend to move by flowage toward the direction of least pressure. The depth at which this method of deformation becomes effective has been estimated by calculation and experiment at from 6 to 12 miles, the latter being perhaps the maximum for the very hard resistant rocks. The influence of this mechanical action is augmented by the heat incident to the depth at which it takes place and no doubt also by occluded waters and gasses which facilitate the solution and recrystallization of the minerals.

The characteristics that are thus produced in rocks by compression within the earth's interior are quite different from those originally inherent in either igneous or sedimentary types and belong to the metamorphic class. Members of the latter, like most igneous rocks, possess a crystalline development, each mineral having crystallized acording to its definite habit, but there are differences in the arrangement of the minerals which is quite typical. Instead of a uniform distribution that arises from the cooling of an igneous magma, producing a homogeneous aspect, whatever plane may be exposed to view, they show a parallel structure and

Plate I

Photo by G. van Ingen

Joint structure in horizontal sediments, Ausable Chasm. The course of the main vertical joints is followed by the river.

their appearance varies with the direction of the surface with respect to the structure. This parallelism is brought about by the linear arrangement of certain constituents like mica or hornblende which have tabular or elongated forms; or it may be produced by the separation of unlike minerals in layers. There is some analogy between such structure and that of stratification in the sediments. But it is no criterion as to the origin of the rock for it is quite prevalent among those of igneous derivation. This structure is commonly called foliation or schistosity. It denotes usually weakened cohesion between the minerals; and rocks split more evenly along the foliation than in other directions.

The changes accomplished by metamorphism are not limited ordinarily to a physical rearrangement of the constituents. In many instances there results also a breaking up of the mineral compounds and their crystallization in new forms, more stable under the conditions. The degree to which the chemical alteration may be carried depends upon the nature of the rock and the agencies at work upon it. An igneous rock like granite under the same influences is more resistant to chemical changes than a sediment like shale. In fact, granite undergoes little alteration beyond the crushing down of the quartz and feldspar crystals and possibly a certain amount of recrystallization, producing a parallel appearance. The basic igneous rocks (those with low percentages of silica) in which the iron, magnesia and lime compounds are well represented, are more prone to chemical change; they form readily such rocks as amphibolite, serpentine and various schists. Among sediments, the limestones are recrystallized into marbles, but in the presence of silica and other compounds existing as original impurities or later introduced, they may be converted into garnetiferous, tremolitic or micaceous schists or amphibolites. Sandstones are hardened by secondary growth of the quartz grains or by deposition of silica cement so as to form quartzites. Shales are converted into slates, with microscopic mica and feldspar crystals; or by further metamorphism into schists and gneisses. Inasmuch as the agencies of metamorphism are mainly restricted to the deeper zones within the earth, the rocks which bear widespread evidence of their effects must at some time in their history have been buried far below the surface. It is only through removal of many thousands of feet of overlying rock by erosion that they are now exposed to view. They are found, therefore, among the older geological formations and include the very earliest members of which we have knowledge.

ROCK STRUCTURES

The physical features associated with the field occurrence of rocks may be considered under the head of structures. Such features include joints, faults and folds, to name some of the more important.

Joints. One of the most evident characters, common to all rocks whatever their origin, is due to the divisional planes that intersect the bodies so that they are never continuous solids, but are broken up into small blocks. These divisional planes or joints may be but a few inches apart, or they may occur at intervals of 50 or 100 feet. In fact, there is every variation almost in their frequency and in their direction with respect to each other. Very commonly there are three sets of joints which intersect at high angles, producing nearly rectangular prisms; this form is quite characteristic of the sedimentary and of the coarser-grained igneous rocks; but no absolute rule can be laid down for their occurrence. Their attitude with respect to the surface contours and their spacing are important points to be considered in the location of quarry sites, especially if the stone is to be used in dimension or monumental work.

Joints are in part primary characteristics, that is, they have been produced in the natural course of consolidation of rocks, and in part arise from stresses externally applied after the rocks were consolidated. The former kind is illustrated by the prismatic or columnar jointing found in exposures of fine-grained igneous rocks such as have cooled in narrow channels or near the surface. Fine examples are to be seen in the Palisades diabase. Such jointing is the result of strains set up in the process of cooling and proceeds always at right angles to the exposed surface.

In the sedimentary rocks, the bedding is a plane of weakened cohesion among the mineral particles and thus marks a direction of potential jointing which probably may result in actual separation on exposure of the beds to drying. The sedimentary rocks also exhibit joints that intersect the bedding at right angles, and in some cases they may be referred to the same cause, contraction on evaporation of the contained water.

It is generally considered, however, that joints are mostly secondary fractures resulting from externally applied stresses. Compression arising from crustal readjustments, or torsional and vibratory strains incident thereto, is given the greatest importance in recent contributions to the subject of jointing. The application of a single stress may be resolved into two components at right angles to each other and forming an angle of 45° with the direction of the

Plate 2

Photo by J. N. Nevins

Joint structure, Little Falls syenite. Vertical and horizontal joints in an igneous rock.

stress. Thus two joint systems arise from a single force and even more complex fractures may result, as has been demonstrated by Becker.[1]

In most rock exposures there are at least two systems of vertical or highly inclined planes nearly at right angles, and one that lies approximately horizontal, or in the sedimentary and metamorphic rocks, follows the bedding or schistosity.

The joints in one direction may be more clearly marked and persistent than in other directions. They can be divided into principal joints and minor joints. The latter often originate and die out in a short distance, but the major joints are likely to continue over wide areas. Within the crystallines of the Adirondacks, the most persistent joints have a northerly to northeasterly trend with a complementary set at right angles.

A series of closely spaced vertical joints is known to quarrymen as a heading. The zone of broken rock is used as a back or heading to work against. In such close jointing, there is often evidence of more or less faulting in the smoothed and striated surfaces and the formation of secondary minerals. A weathered appearance is also characteristic of such zones, as they serve as channels for the admission of surface waters.

The igneous rocks, especially those like granite that occur in bosses and knobs, show at times a series of close-set fractures, horizontal or slightly curved in conformity with the surface, that divide the mass into parallel plates. This is known as sheet structure and is common in many of the New England and southern granites, but appears to be rare in the Adirondacks, at least in its more typical form, although some quarries show incipient or imperfectly developed sheets. The origin of this structure has received much attention from geologists, with the proposal of various explanations. Since the fractures follow the surface contours in most cases and gradually diminish in their frequency and strength with depth, there seems to be good reason for connecting them with some superficial process like the strains set up by temperature variations. The subject is well discussed in Dale's reports on the quarries of the New England States.[2]

Faults. The phenomena incident to displacements of the rocks along fractures are quite common in the crystalline areas, and also

1 Proceed. Washington Acad. Sci., v. 7, July 1905, p. 267–75.

2 For example, "The Chief Commercial Granites of Massachusetts, New Hampshire and Rhode Island." U. S. Geol. Sur. Bul. 354, 1908, p. 22–29.

in the older stratified formations. They result from strains in the outer zone of fracture and thus are connected with the formation of secondary joints. As already noted, a system of very marked jointing is often accompanied by differential motion of the rocks involved, which is denoted by their polished surfaces. When the displacement is considerable, the rocks along the fracture are much broken and sometimes mashed into a mineral pulp in which much alteration has taken place.

Fig. 1 Simple faults. *a* illustrates the common or normal fault, and *b* the reversed fault

Faulting is most common and of the greatest magnitude in the Adirondack area of which the whole eastern and southeastern boundaries between the upraised and folded crystallines and the horizontal Paleozoic sediments are defined by a series of faults. Like the massive joint systems of that section, they have a northeasterly to northerly trend; their downthrow is toward the east. Some of the interior Adirondack valleys are undoubtedly the result of faulting, either of single or compound type, but in this case, the evidences of actual displacement are not so apparent since it is confined to the crystallines alone. Valleys with abrupt slopes on both sides may be due to the sinking of the block between two faults, as is thought to be the origin of the Lake George basin. There is need of caution, however, in ascribing the existence of scarps and deep valleys in this region to faulting, as the normal course of weathering and particularly the wear of glacial ice would tend to produce sharp contours along the main joint systems.

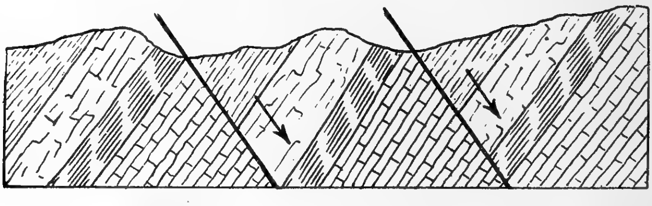

Fig. 2 Normal faulting in inclined strata; the same beds outcrop repeatedly when traced across the strike

Plate 3

Photo by S. R. Stoddard

Great fault fissure on Avalanche lake, Adirondacks

For present purposes, it is not necessary to enter upon a discussion of the various types of faults and their effects upon rock structure. They are generally to be avoided in the laying out of quarries. If the aim is to produce crushed stone, their presence may not be objectionable, but even helpful; though care must be used lest the rock be decomposed or so shattered by the faulting as to lose its qualities of hardness and toughness. In mining engineering they are of great importance, and they should be given due consideration also in the plans for permanent foundations and structures, as they mark the lines along which future crustal disturbances may occur.

Folds. The original arrangement of the sedimentary rocks, as determined by their deposition layer by layer upon the flat or slightly sloping sea bottom, is that of a series of parallel and nearly horizontal sheets. Upraisal into land may take place so gradually and uniformly as to preserve this attitude almost unchanged. Thus the great belts of limestones, shales and sandstones which occupy practically all the State south of the Mohawk and west of the Hudson, show almost no relative disturbance throughout their extent, although they have been elevated through a range of 2000 feet or more. When some of the formations are traced eastward from the Hudson toward the New England border, they rapidly lose the appearance of horizontality and assume inclined positions so as to present their upturned eroded edges to the surface. The new arrangement reflects the influence of lateral compression in bending and folding the strata so as to bring them into smaller compass.

The development of folds or flexures can be traced in the rocks through all stages from simple to very intricate forms. Every case of folding, however, may be reduced to a variation of two simple basic types, that of the uparched or saddle fold and the inverted type or downfold. The former, called an anticline, is recognized in the field, where the arch itself is concealed or eroded away, by the inclinations of the same beds in opposite directions from the central line or axis. The second type, called the syncline, has inward sloping sides which meet to form a trough.[1]

Simple open folds may have symmetrical limbs which are inclined at the same angles. This is rather exceptional and the sides more

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[1] The attitude of folds in the field is found by taking observations of the inclinations and direction of the beds referred to the horizontal plane. The angle of greatest inclination to that plane is the *dip*; and the direction of outcrop with reference to the true north is the *strike*.

often show different inclinations. The close, compressed folds have straight sides which dip in nearly the same direction. The arches in such cases are often overturned so that one side rests upon the

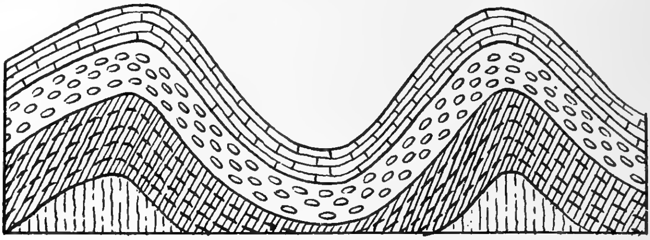

Fig. 3 Folded strata, showing a syncline bounded by two anticlines or saddles

other. Examples of the open types of folding are found in the strata that lie on the borders of our mountain areas and are occasionally seen in the limestones and sandstones of the Mohawk and central Hudson valleys. In the interior of the mountains, the folds become compressed or overturned and develop minor flexures, superimposed on the larger ones so as to produce a very complicated structure.

Folding of the intense kind is accompanied by metamorphism. The metamorphic rocks like marble, slate and schist are invariably highly folded. So intricate is the result of this folding upon the crystalline rocks of the Adirondacks, followed as it has been by profound erosion, that the nature of the flexures are only rarely determinable, though the high angles of dip and their conformity for considerable distances indicate strongly compressed strata.

The crystalline limestones and marbles, owing to their uniformity and the readiness with which they yield to stress by plastic movement, often effectually conceal the existence of folds. When seams of slightly different character or stringers of foreign materials are present, these will generally be found to be bent into a succession of winds and inverted folds that exemplify in limited compass the actual contortion that has taken place on a large scale.

Fig. 4 Folding of the Paleozoic strata in the vicinity of Kingston, N. Y. After N. H. Darton

Great masses of igneous rock, like the areas of granite, syenite, and anorthosite in the Adirondacks, undergo much less shortening from compression when once they have consolidated. The very early gneisses of probably igneous derivation have a lenticular or belt-like form with the large axis parallel to the general structural trend and have thus been influenced to some extent, though they were perhaps squeezed out somewhat while still molten. In general, the igneous masses serve as a buttress, against which the thrusts that fold the sedimentaries have little effect.

DIFFERENTIAL PARTING

Many rocks as found in the field show a capacity for splitting along one or more planes. This feature, when well developed, is of great advantage to the quarryman and stone dresser and upon its existence depends in great measure the availability of stone for many commercial uses. There is naturally marked variation in the behavior of rocks in regard to parting, not only between the different classes — igneous, sedimentary and metamorphic — but also among members of the same class, so that each occurrence must be separately tested for this structure.

In the sedimentary class, the direction of easiest parting coincides usually with the bedding. In the finer mechanical sediments like bluestone and shale that have been sorted and deposited by water, the structure is often exhibited in great perfection. In this case, it may be traced to the presence of platy and elongated particles among the constituents, or else to a regular alternation of finer and coarser materials parallel with the bedding planes. The chemical precipitates, which are mainly represented by limestones, show it much less frequently, being often incapable of smooth fracture, although subdivided by natural seams or joints. For that reason limestones are often stronger and more resistant to wear than the other sediments, and are specially adapted for crushed stone in road-making and concrete.

The best example of this parting among sedimentary rocks is found perhaps in the flagstones which are mostly made of fine-grained sandstones that in New York are abundant in the Devonic formations. They are locally known as bluestone, though that term is not always expressive of their appearance. Between the bedding planes of the sandstones occur closed seams which are indicated by a slight change of grain and are spoken of by the quarrymen as "reeds." According to Dickinson,[1] reeding quarries are found generally in the fine-grained stone and each locality or

[1] Quarries of Bluestone and Other Sandstones. N. Y. State Mus. Bul. 61, p. 7–8, 1903.

quarry has its own characteristic reeds. Berkey[1] states from observation of the bluestone in the Catskills that the capacity for splitting into slabs depends upon the abundance, arrangement and size of the elongated and fibrous grains. The reeds are marked by a darker color and finer grain than the body of the rock. The structure is partly original and partly arises from changes subsequent to the formation of the bluestone, whereby the fibrous appearance has been accentuated.

The massive igneous rocks, of course, are devoid of any capacity for cleavage comparable to that in bedded types. But none the less, they oftentimes possess a differential parting which greatly facilitates their manipulation in the quarry. Quite commonly the parting takes place in two directions at right angles to each other. The line along which the stone yields most readily is known as the rift; it may lie in any plane, but is more often, perhaps, nearly vertical. The direction of the second easiest cleavage is called the " grain " or sometimes the " run." Though many quarry stones seem to possess only the two lines of smooth fracture, there is occasionally a third, along which they may be broken with some degree of ease and which is known as the " head." This is less easily detected than the others, because it approaches the normal fracture of the stone.

Rift and grain are frequently described in works on the quarry industries with special reference to the granites. From the information given, the impression might be gained that these structures are only characteristic of the granites, though such conclusion is by no means warranted. The syenitic rocks of the Adirondacks often show a fairly good cleavage in two directions. Other examples of rift which may be compared with the same structure in granites are to be found in the crushed but massive-appearing anorthosites, such as those quarried in the northern Adirondacks, near Ausable Forks and Keeseville. This rock is almost entirely made up of lime-feldspar (labradorite) though some phases contain quite a little pyroxene and garnet. It splits readily in two directions so as to be easily dressed into dimension stone or paving blocks. The igneous rocks of the gabbro class, in which large percentages of pyroxene or amphibole are present, seem to lack the structure in anything like the typical development of the more acid rocks.

[1] Quality of the Bluestone in the Vicinity of Ashokan Dam. School of Mines Quarterly, v. 29, no. 2, p. 156–57.

The cause of rift in the igneous rocks has been variously explained. Some writers have attributed it to a slight foliation produced by parallel arrangement of the mica minerals. In such cases, it is comparable to the foliation cleavage of the metamorphic

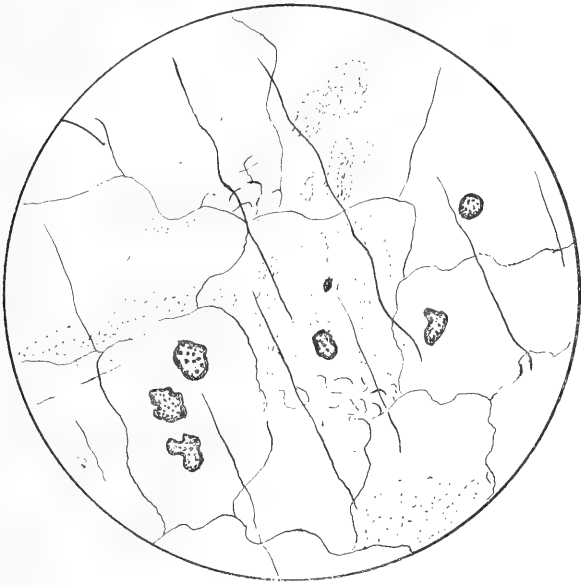

Fig. 5 Microscopic fractures in anorthosite, parallel to the rift or direction of easiest cleavage. The section is nearly pure feldspar, the small grains being garnet. Enlarged 25 times

rocks. Another cause may be found in the regular arrangement of the feldspars so as to bring their cleavages into alignment, as has been described for a Norwegian syenite. Perhaps the more common type of rift, specially in the granites, is that produced by the presence of microscopic fracture lines. Tarr, Whittle and others have noted many examples in which the cleavage arises from very minute hairlike fractures, individually somewhat irregular and discontinuous, but in general holding their direction unchanged throughout the rock mass. Such fractures are found in both quartz and feldspar. Dale[1] more recently has shown that rift may be related to minute cavities in the quartz, the cavities being arranged in parallel sheets which, in some instances, are accompanied by parallel fractures.

Among the metamorphic rocks, a foliated or gneissoid structure is usually accompanied by cleavage along the planes of foliation.

[1] U. S. Geol. Survey Bul. 354, p. 42–47, 1908.

The appearance of foliation is due to the parallel arrangement of the prismatic and scaly minerals or to the elongation of the quartz and feldspar, accompanied by more or less segregation of the constituents in alternating bands. Some rocks evidence the effects of metamorphism by granulation and recrystallization, without the development of any marked foliation. This is true of the light-colored feldspar-quartz gneisses and of the purer feldspar anorthosites that are common in the Adirondacks. These rocks, when crushed, present a massive appearance and have a smooth fracture in two or more directions, instead of a single cleavage, like the typical gneisses.

CHEMICAL AND PHYSICAL PROPERTIES OF ROCKS WHICH INFLUENCE THEIR COMMERCIAL USES

Chemical composition. The determination of chemical composition may afford much information as to the availability of rocks for different purposes. Its service in many cases, however, may be said to be rather of negative value, as determining the presence or absence of certain harmful constituents and as a test for the relative decomposition which a rock has undergone under surface weathering. The analysis is of most value when used in connection with the results of microscopic study.

Limestones are employed in large quantities by chemical and metallurgical establishments, and here an analysis is the first consideration. For some uses a magnesian limestone may be preferred; for others a high calcium variety is wanted; but nearly always the demand requires a limestone with low percentage of impurities in the form of silica, alumina and iron. For Portland cement manufacture the presence of the first two ingredients is rather an advantage, as they take the place of so much clay or shale. For building or engineering work, the analysis plays little part in deciding upon a suitable stone.

With sandstones the chemical analysis is useful mainly as a guide to the character of the cementing substance, since the sand grains themselves are chiefly quartz. Feldspathic sandstones, which are indicated by the presence of alumina, lime and alkalies, are less durable than the pure quartz kinds, but ordinarily good enough for most construction work. In the case of the igneous rocks, chemical composition has some practical significance, though its place can be supplied often by a careful study of the constituent minerals as usually carried out with thin sections under the microscope.

The percentage of silica determines whether the rock is to be classed with the acid (over 65 per cent SiO_2), intermediate (55–65 per cent), or basic (below 55 per cent) groups. In the first group free quartz, which is the most resistant of all minerals to alteration and one of the strongest, is present in quantity. All granites belong to that group. The intermediate group consists mainly of syenites and diorites in which potash and lime-soda feldspars are the main ingredients. These show a higher resistance to physical disintegration than granite, but they are perhaps a little more open to chemical alteration. In this group may be classed also the anorthosites which are made up of lime feldspar and subordinate pyroxene and which are usually classed with the gabbros in the basic division For all practical purposes they can be considered as equivalent to the syenites. The basic group is represented by the gabbros, pyroxenites, hornblendites and diabases among the more common rocks. They have high percentages of the basic or lime feldspar and of the iron-magnesian minerals, especially pyroxene and hornblende and frequently olivine. They are exceedingly tough, unyielding rocks when fresh and eminently suited for crushed stone, but are too somber in color for most construction purposes. They weather rather rapidly through chemical decomposition with the production of hydrated silicates and oxides, such as serpentine, talc and limonite.

The metamorphic rocks are chemically allied to the igneous or sedimentary types from which they have been derived.

The presence of sulphides in any building or ornamental stone is undesirable. They are indicated chemically by the percentage of sulphur dioxide in the analysis. Pyrite and marcasite, the common sulphides in rocks, break down readily in the atmosphere to iron oxides which cause unsightly stains upon the surface, though not ordinarily weakening the structure of the rock itself.

The percentages of carbon dioxide and water in igneous rocks afford valuable criteria as to their relative freshness. Carbon dioxide indicates the presence of calcite which results from the decomposition of feldspar and some of the other silicate minerals. Water in amount above a small percentage is also traceable to secondary products like kaolin, talc and serpentine.

Mineral composition. According to their relative importance, the rock-forming minerals may be divided into (*a*) essential ingredients and (*b*) nonessential or accessory ingredients. The former constitutes the bulk of rock masses, commonly all but a few per cents of the whole; and includes all those that have any considerable influence upon the physical properties and fitness of the materials for economic uses. There are a few exceptions to be made with reference especially to the iron oxides and iron sulphides which occur in small amounts, but yet are important, the former as coloring agents and the latter owing to their tendency to decompose in the atmosphere and cause unsightly stains.

The various representatives of the igneous rocks are combinations of a small number of essential minerals. A list of the more important minerals includes quartz, feldspar, mica, amphibole, pyroxene and olivine. If to these be added nephelite, sodalite and leucite, which occur in certain areally restricted but not altogether rare types, the list of essential ingredients for the igneous class is complete.

It may be noted that all the minerals named contain silica. Quartz is silica alone, while the others are compounds known as silicates in which silica functions as an acid and combines with some of the basic elements like sodium, potassium, magnesium, calcium, iron and aluminum, to name the more common ones. Several of the minerals, namely, feldspar, mica, pyroxene and amphibole, are not single species, but mineral groups with a number of individual species possessing similar but not identical chemical and mineralogical properties.

The strength and durability of the igneous rocks in ordinary service are conditioned by the nature of the constituent minerals and the manner in which they occur. The harder and more durable ingredients are quartz and feldspar, consequently the rocks that are made up of them in larger part are the most serviceable under equal conditions. Quartz is not subject to chemical decomposition, but feldspar yields slightly to atmospheric agencies and in the course of time may become softened so as to crumble under pressure. The iron-bearing silicates which are represented by mica, amphibole, pyroxene and olivine are also subject to change under the weather, with the result that the iron is partly discharged from combination as limonite, and new combinations of silica characterized by the presence of water in considerable amount are formed. Chlorite, serpentine and talc are common secondary minerals resulting from their alteration. It may be noted that while such changes have taken place in nature on a great scale, the element of time has been a factor for which no equivalent can be found within the limits of human experience. As a matter of fact, almost any mineral combination among the igneous rocks, provided the ingredients are not already in weathered condition, is durable enough to serve the purpose of ordinary building construction. There is little choice, so far as mineral composition is concerned, to be made between a granite, a syenite or a gabbro. From the standpoints of toughness and resistance to abrasion, which are important qualities for concrete and road materials, the syenites and the more basic rocks are likely to prove superior to the granite.

The sedimentary rocks may be classified by their mineral content into (*a*) arenaceous materials represented by sandstones and conglomerates, (*b*) argillaceous materials or clays and shales, and (*c*) calcareous materials or limestones. They have a simpler mineral composition than the igneous types. Sandstones are composed of granular quartz held together by some cementing substance. This may be a secondary deposit of quartz, in which case the rock is called quartzite; or one of the iron minerals, like limonite or hematite. The argillaceous members consist of very finely divided clayey substances with more or less quartz, calcite, iron ores, etc. They are too soft for constructional stone, but under metamorphism yield slates, schists and gneisses. The limestones consist of the mineral calcite alone, or calcite admixed with dolomite, in the latter case being called magnesian or dolomitic limestones.

Between the groups of limestones and sandstones as a whole, there is no comparison possible with regard to durable qualities. If the nature of the respective components (calcite and quartz) alone were to be considered, sandstone would be far superior, but there are other factors entering into the question. The size of the constituent particles, the porosity, and the character of the cementing substance, if any, need to be taken into account.

With sandstones, the character of the cementing substance is more important than any other feature. Some contain very little cement, being held together by the surface adhesion of the particles when brought into close contact. These are apt to be friable and little resistant to physical disintegration. Calcite is a common cement, but rather inferior, since it seems to lose its attachment to the quartz with weathering, and the rock becomes a sugary aggregate. Iron oxide in the form of hematite forms a durable binder and provides an attractive color.

The highest grade sandstones in respect to hardness, toughness and permanency are those in which the grains are bound together by quartz. Such types are called quartzites and are exemplified by many occurrences of the Potsdam sandstone in this State. When the secondary quartz is united with the grains to build them out into interlocking crystals, as sometimes happens, the material is the most durable of all constructional stones.

Limestones are made up mainly of the calcareous skeletons of organisms, though often so finely comminuted as to be unrecognizable to the unaided eye. There is also more or less of secondary calcite, derived by solution and redeposition of the lime, which serves to fill up the interstices and the interiors of the organic remains. The calcite shows crystalline character, but is not so uniformly developed in rhombic particles as in the case of marbles. Besides calcite, the double carbonate of lime and magnesia, or dolomite, may be present in similar form. Through its increasing participation, the magnesia may replace the lime up to 20 per cent or so.

Though calcite is quite soluble in rain water and groundwaters which contain carbon dioxide, limestones, when compact and well cemented, are sufficiently durable in the mass to withstand all ordinary conditions of exposure. The purer varieties are the best. The presence of argillaceous and siliceous impurities tends to weaken their structure, as there is not the same bond between particles of different nature as exists between the uniform calcareous grains.

The metamorphic rocks require no special mention. In their mineralogy, they are related to the one or the other of these classes. Metamorphism ordinarily produces small changes in the igneous rocks so far as their mineral ingredients are concerned. With the sediments it tends toward recrystallization of the ingredients, thus making them more compact or harder than the originals, with an approach, in the case of the siliceous sediments, to the structures and mineral contents of the igneous class.

Texture. There is no doubt that texture (by which is meant the size, form and spacing of the mineral particles) plays an important rôle in the strength and durability of rocks. The relationship, however, is not always so distinct or easily grasped as might be inferred from the treatment given in some works on quarry materials. As a rule, each quarry presents features that require individual study, not alone by themselves, but with reference to the geological history and mineral content of the material.

The size of grain obviously affects the appearance and physical qualities of rocks. It is not (contrary to the opinions frequently expressed) an index of their porosity or resistance to weathering influences. Tests show that a fine-grained granite may be as porous as a coarse-grained one, which is also true of a sandstone. There is usually a difference in the size of the pores, which are larger but less numerous in the coarser stones; consequently, it may be said that these will usually absorb moisture more readily and on the other hand dry out more quickly than similar rocks composed of particles in a fine state of division. Whether they weather more or less rapidly than their fine-grained equivalents, depends upon other factors such as the state of aggregation and relative spacing of the particles and the character of the climate.

Experiments with the St Lawrence and Jefferson county granites indicate that the coarser grades, which contain feldspars up to an inch in diameter, are as closely textured as the fine sorts. There is also no appreciable difference in the two kinds with regard to weathering, so far as can be estimated from the condition of the rocks in natural exposures.

Crystalline rocks which have consolidated at depths show little porosity, and the variations between different examples are often too slight to have significance for practical purposes. Any marked departure from the average is traceable to external influences in the way of chemical or mechanical disintegration and should be an occasion for careful investigation.

The fragmental rocks like sandstone and grits are apt to have more pore space. But a degree of porosity above the average is indicative of imperfect cementation. It denotes, therefore, perviousness to moisture, as well as inferior strength through lack of bond. Limestones and marbles may be quite as impervious as the igneous rocks. Porosity in their case may arise from solution by the seepage of underground waters, forming cavities which weaken their structure and not infrequently contain secondary deposits of iron sulphides.

Apart from these considerations, the size of grain seems to bear some relation to the strength of certain rocks. This has been noted by Julien,[1] who instances the minutely crystalline limestones as examples which may show surprising resistance to crushing; in a limestone from Lake Champlain the ultimate strength reached 25,000 pounds to the square inch. The explanation for the superior strength of such rocks, as given by that writer, is that the molecular cohesion between the grains, under equal conditions, is proportion-

[1] Building Stones — Elements of Strength in their Constitution and Structure. Journal of the Franklin Institute, v. 147. April 1899.

ate to their fineness. The apparent exceptions to this relation of grain to strength are numerous, but they are possibly accounted for by variations of interlockment and cementation between the particles.

An important element in the strength of some rocks is contributed by the interlockment of the particles, an arrangement which acts upon the general structure like hair in a mortar. This is exemplified best of all by the diabases in which the feldspar in lathlike crystals is embedded in a matrix of pyroxene, olivine and magnetite, so as to exert the utmost resistance to both tension and compression. A similar effect may be produced by prismatic hornblende and pyroxene crystals in the syenites and gabbros or by the mica scales in granites. A dovetailing of the mineral particles contributes to the strength of some marbles and granites. The grains have irregular or indented outlines instead of smooth, rounded borders and are molded upon each other in the closest form of interlockment.

A uniformity of texture with the minerals spaced after a regular pattern is an advantage both from the standpoints of appearance and of weathering qualities. It is essential for rocks that are to be subjected to abrasion and wear.

Color. Little significance attaches to color as a guide to the intrinsic merits of building stone. Within narrow limits it may indicate something in regard to the relative state of weathering but a change of color such as may be brought about by oxidation of iron or bleaching of carbon compounds on exposure to the air does not necessarily mean a deterioration in strength. From commercial considerations, however, color ranks among the very important qualities and has much to do with the favor which a stone wins in the market. This is especially true of architectural stone for use in our larger cities. There is a certain prevailing taste apparent in the selection of stone with reference to color which finds illustration in city architecture of different periods. At present, the taste seems to incline toward the very lightest colors, white or light gray, often to the exclusion of shades which are much better adapted for service in the surroundings. The employment of white marbles and very light granites for structures in manufacturing districts or for railroad stations seems inappropriate as it is unnecessary.

The colors found in rocks are too varied to be individually discussed or explained. It may be said that the principal coloring agents are iron and carbon, the former for the igneous class and the two together in sedimentary rocks. Iron occurs in chemical combination chiefly in the silicate minerals like biotite, hornblende, augite and olivine, lending various shades of green or a black color to these ingredients of the crystalline rocks. It also occurs in the form of free oxides, sulphides and carbonate distributed through the body of the rock. The yellow, brown and reddish tints are mainly due to the oxides of iron, blue and gray to the carbonate. Carbon occurs in finely divided particles which lend a black or bluish color to certain limestones, marbles and slates.

The presence of iron in a condition of incomplete oxidation, as ferrous oxide or carbonate, or as a sulphide, is detrimental to building or ornamental stones. The original colors incident to their presence will not prove permanent. In some classes of material, the change which takes place by oxidation of these compounds produces a desirable mellowing effect, as in the Hudson River sandstones, but ordinarily it leads to red or yellow blotches. The colors resulting from the oxidation of pyrite and marcasite are also apt to run, forming streaks which extend outward from the particles and are quite frequently seen in exposed walls. Some measure of the permanancy of color in building materials may be had by a chemical analysis giving the percentages of unoxidized iron. Allowance should be made for the nature of the compound, for the mineral magnetite which contains both ferrous and ferric iron is more stable under atmospheric weathering than a ferrous compound like the carbonate. In fact magnetite is extremely resistant to change and its occurrence can not be held as a drawback to the use of any stone.

Besides the change of color that takes place in building stones through the relatively slow alteration of the components as noted, there are well-known instances where changes occur almost immediately on removal of the stone from the quarry. The nature of this change is not fully understood, but it seems to be connected in some cases with the loss of the quarry moisture or sap. As a local example may be cited some of the occurrences of the Adirondack green syenite which have a lively light to dark green color on fresh surfaces but which change within a few days to a yellow or muddy green. The change is unaccompanied by any discernible effect with respect to the mineral ingredients, and, though it seems to be connected with the loss of moisture, the original tint can not be restored by long-continued immersion in water.

The appearance of stone in a building can not be summed up entirely under color. Some kinds have a bright, clean look which others of similar color lack. There is a strong contrast in that respect between Gouverneur marble, for example, and a noncrystalline granular limestone. The nature of the surface exposed to view also must be taken into account; in the darker stones, a marked difference usually exists between the rock face and the hammered surfaces, the latter being much lighter. The appearance of a stone in a small sample may fail to give the actual effect when seen at some distance in the walls of a building.

The granites and related silicate rocks ordinarily change very little, even on long exposure to the weather. Their coloration is lent by the inherent colors of the various minerals, rather than by the presence of some accidental ingredient diffused through the mass. In consequence of their usually complex mineral composition, they appear mottled or speckled on close view and only assume uniform tints when viewed from a distance. The coarser the texture, the greater is the distance required to produce blending. Among the ingredients of igneous rocks, quartz exercises little part in the coloration, itself being colorless or at most grayish or whitish. Feldspar is the mineral to which the granites, syenites and anorthosites owe their characteristic colors. In the granites, it is mainly white, cream or light pink, but is sometimes deep red. Its effect is toned down by the darker minerals, so that the brilliant white or red becomes gray or dark red in the body of the rock. The feldspar in syenite may be pink or gray, but is not infrequently blue or green. The feldspar (labradorite) of anorthosite has a dark green to almost black color in fresh condition, but shows nearly white when crushed and subjected to slight alteration. In the diorites, gabbros and diabases, the dark silicates, like biotite, amphibole and pyroxene, share importance with the feldspar and consequently these rocks possess rather somber tones.

Strength. The resistance which rocks offer to stress when applied to their surface varies much with the class and type. It depends upon many different factors which are mainly related to the mineral composition and texture, but which are also influenced by external conditions. Some of the relations between the physical characters of rocks, particularly textures, and strength have already been mentioned.

The igneous rocks as a class are distinguished from the other rocks by the fact that their strength is uniform, irrespective of the direction in which the stress may be applied. This depends, of course, upon their homogeneous composition and texture. In the sedimentary and metamorphic classes, the planes of bedding or schistosity mark a weakened cohesion between the constituents which may lead to a very considerable variation in their strength, according as the latter is tested parallel with or normal to those planes. Variations of strength do occur in the igneous rocks, notably such as possess rift and grain structures, but to a minor degree as compared with the other classes.

Mineral composition affects the strength of rocks, though in general it is less important than the features connected with texture. Such a weak material as serpentine shows surprising compressive and tensile strengths when the fibers of which it is composed are thoroughly interwoven. Marbles and limestones of nearly uniform composition exhibit a wide variation in tests with variations of grain and compactness of texture. On the other hand, the presence of hard resistant minerals like quartz, hornblende and pyroxene no doubt contribute to the strength of certain igneous rocks.

The resistance of the stone to stress necessarily differs with the method of application, and the behavior of a sample under compression, which is the usual method of testing strength, does not afford any valuable information as to the resistance the stone will offer to tensile or bending stresses. This fact is very well brought out by the cracking of arches and lintels under transverse strains, whereas the same forces applied in compression have little or no effect.

The strength of stone is often injured by lack of proper care in quarrying. Stone that has been blasted from the ledge by dynamite or powder can not be expected to exhibit the same strength as that quarried with the use of the drill and wedges. Even if there are no visible cracks or checks, it will be found that the blasting has worked damage to the texture by loosening the bond between the particles.

Other conditions which affect strength are the weathering and drying out of the stone after removal from the quarry. Some soft sandstones show a remarkable gain in strength when exposed to the sun's heat and the consequent evaporation of the quarry sap. When saturated again, they lose some of this acquired strength, but are still more resistant than the freshly quarried rock; exposure to a wide range of temperature is, however, detrimental to any stone.

THE EXAMINATION AND TESTING OF STONE

The availability of any stone for commercial use depends first of all upon the features connected with its field occurrence. Geological observations are necessary to determine the quantity of material that can be readily quarried; the physical conditions affecting the course and economy of quarry work; and the general character of the stone with regard to color, texture and the larger structural variations incident to inclusions, segregations, dikes and veins. Even liberal samples collected with a great deal of care fail to convey the same information respecting the general features of the stone that is gained by an inspection of the exposure or quarry pit itself.

The next consideration is to establish the physical properties of the stone so as to be able to forecast with some certainty its relative fitness for the special service that may be demanded of it. This information is afforded by mineralogical and chemical investigations supplemented by physical tests along the line of those adopted for estimating the strength and durability of other structural materials. Furthermore, a comparative study of the behavior of different quarry stones under conditions of actual service will be helpful in applying the results obtained by laboratory experimentation. In fact, physical tests alone may lead to erroneous conclusions as to the relative value of samples, and the guidance obtainable by observations of materials of similar nature in actual service is highly essential in forming an estimate.

QUARRY OBSERVATIONS

The field relations of quarry stones may be said to comprehend practically the whole range of variations of rock occurrence. Their interpretation requires a broad knowledge of the origin and structure of rocks and the modifications produced by surface agencies which can hardly be presented here. Such knowledge is in part to be found in any standard work on geology and in part rests upon personal experience gained by study in the field. Only a few general matters will be given attention here.

The granites and related igneous rocks ordinarily occur in large bodies and are continuous for indefinite distances into the earth. The question of quantity of material is not so important, therefore, as the situation with respect to ease of quarrying. The most advantageous situation for quarry work is along the side of a hill, as it facilitates the handling of the stone and secures natural drainage. The direction and frequency of joints exert much influence upon the relative ease of obtaining blocks and also determine whether stone of size for building and monumental work can be had. A rift and grain structure is necessary if the stone is to be used for dimension work or paving blocks.

Variations in the character of the igneous rocks are produced by pegmatitic and aplitic segregations and dikes, by quartz veins, and by inclusions of foreign materials that have been involved in the mass during its progress toward the surface. These are detrimental to uniformity of the product, or may necessitate the discarding of much material in the quarry work. They are not so important in case the stone is to be used for engineering work in which appearance is a minor consideration.

With the sedimentary rocks, the dip or inclination of the beds is a matter of importance. With ordinary quarry materials exploitation under cover is impracticable on account of the cost, though it may be adopted in the case of marble or slate. The thickness and succession of the beds, the presence of shale partings, variations of texture and color, and the spacing of the joints are features to be noted. When the beds lie nearly flat and their edges are not exposed in nearby stream valleys, it may be necessary to prospect the beds by test holes. For that purpose, a diamond or shot drill is used and the cost of securing cores by such method may be expected to amount to several dollars a foot; ordinarily, only shallow holes are necessary, but the expense is proportionately large on account of frequency of moving and setting up the drill.

The sedimentary rocks, unless broken and faulted by dynamic agencies, may be expected to extend over wide areas. It is not safe, however, to rely on the continuity of individual layers for any considerable distance without evidence in the matter. In the clastic rocks like sandstones, especially, the character of the beds may change quite rapidly, or the layers may wedge out to be succeeded by others of different color or texture. This feature is well illustrated by the Medina sandstones which are subject to rapid variations along the strike, the heavy and valuable beds becoming thin or shaly within short distances, though on the dip they are apparently more persistent. The use of the core drill will often effect a large saving in the development work of quarry properties.

The value of observations in the field as to the durability or weathering qualities of stone is not of much consequence. At most, they can be used only to compare the relative resistance of different materials when exposed to similar conditions. That the conditions depend much upon the topography and the character of the soil covering appears very evident and the variations in these respects may overbalance the factors inherent in the stones themselves. Thus the evidences of weathering are more apparent in valley bottoms where the process of decomposition and disintegration is cumulative in its effects than upon a hill where the products are removed nearly as rapidly as they are formed. In a glaciated country like this State, the presence or absence of bowlder clay is an important feature in determining the effects of weathering. When that material rests directly upon rock, the latter is always much fresher in appearance than when covered with sand or soil.

It is now quite generally conceded that no reliable estimate can be made from the weathering qualities of rock in place as to its probable permanency when placed in the walls of a building. That conclusion was reached in the course of an investigation carried out a few years ago by a commission appointed by the Prussian government. The report of the commission, as quoted from Parks' *Building and Ornamental Stone of Canada,*[1] stated that:

> 1 The alterations produced in stone by the agents acting in the crust of the earth are not comparable with those caused by the action of the atmosphere on stone placed in a building.
>
> 2 Changes are produced in the course of the geological ages which can not possibly be effected in the length of time that a building stands.
>
> 3 The obtaining of a measure of the time necessary for distinct alteration to appear in a building stone and for the time required for the alteration to proceed through different stages is not assisted at all by observations on geological weathering.

MICROSCOPIC EXAMINATION

The microscope beyond all doubt is the most valuable single adjunct for the laboratory investigation of structural stone. There is no other method that at once yields so many important facts and with so little outlay of time or expenditure for equipment.

The information which may be had from the examination of rock samples with the microscope include: (1) the identity of the various mineral ingredients, from those of macroscopic size down to the finest particles: sulphides, carbonates and any other harmful components are quickly revealed; (2) the size, form, interlockment or cementation of the grains; (3) the compactness of the rock, or its relative porosity; (4) the condition of the minerals with respect to weathering; (5) the relative proportion of the different minerals. As minerals are definite chemical compounds, the determination of the relative abundance of each variety affords a measure for reckoning the quantitative chemical composition. The results are not so accurate as those obtained by actual chemical analysis, but in ex-

[1] Department of Mines, Ottawa, v. 1, p. 57. 1912.

perienced hands the method can be made to give the essential features with sufficient accuracy for all practical purposes.

The microscope used for rock examination is of special construction, differing from the ordinary instrument chiefly in the use of polarized light which is secured by two Nicol prisms, one of which is placed below the stage and the other either in the tube or above the eyepiece.

Rock samples for examination under the microscope must be reduced to such thinness that they are perfectly transparent. This means a thickness of 0.1 mm or less. The sections are prepared from chips an inch or so in diameter that are broken off from the rock sample with a small hammer, or better from flat pieces cut with the diamond saw. These are ground smooth on one surface with the aid of a lap wheel or glass plate, using emery or carborundum and water for abrasive. When a perfectly flat surface, free of scratches, is obtained, this is cemented to the object glass with Canada balsam. The other side is then ground down until the section is of the required thinness, after which the sample is cleaned and a cover glass cemented on it with balsam. The preparation is permanent and can be filed away for future reference.

To determine the proportions of the minerals in the section, from which determination the chemical composition may be reckoned with some degree of accuracy, the method adopted is that first devised by Delesse [1] and later perfected by Rosiwal.[2] This depends upon the principle that the areas occupied by the several minerals in the section bear the same relations as the respective volumes of the minerals. Delesse made a tracing of the outlines of the minerals, gave each species a separate color, and then applied the tracing to a sheet of tinfoil. The latter was divided carefully along the boundaries of the minerals and the pieces corresponding to each species were separately weighed. The result gave the proportions of the several ingredients. The Rosiwal modification consists of tracing on the cover glass a network of lines equally spaced and intersecting each other at right angles. The ratio of the total length of the lines to the sum of the intercepts of the mineral particles on the lines is approximately the ratio of the total surface to the area occupied by each mineral. The accuracy of the method, according

[1] Delesse, M. A. Procédé mécanique pour déterminer la composition des roches. Paris, 1862.

[2] Rosiwal, August. Ueber geometrische Gesteinsanalysen, Verhandlungen der K. K. geologischen Reichsanstalt zu Wien. v. 32, p. 143–75.

to Rosiwal, is indirectly proportional to the average size of grain of the rock and directly to the length of the selected system of lines.

A further improvement of this method has been recently described by Hirschwald.[1] It consists of a microscopic eyepiece in the focus of which are placed two glass plates, one ruled with a set of ordinates and the other with abscissas, the latter plate being movable along the edge of the first by means of a screw turned with the fingers. The microscope, when focused upon the section, shows the two scales superposed upon the surface; the movable or horizontal scale is used to measure the intercepts of the mineral particles. By readjusting the movable scale, the measurement may be repeated until the area of view is covered. It is recommended by Hirschwald that the measurements be taken at such intervals as to cover the average grains by two or three readings, the number depending on the size of the particles.

The microscopic method of approximating the chemical composition is considered by Hirschwald to be preferable to chemical analysis in some instances. Such is the case with sandstones that contain decomposable ingredients and those of hard siliceous nature, and it serves equally well to determine the amount of cement.

There is need of much care in selecting the samples for microscopic examination to insure that they represent a fair average of the rock. It is also unsafe to depend on the evidence obtained from a single section. As the area of a section is usually less than a square inch, the minerals may not be present in it in the same proportion as in the rock mass, especially if the grain be coarse. Inaccurate results are often much worse than none, as illustrated by the misinformation that is often circulated by quarry owners and which sometimes originates from supposedly reliable sources.

CHEMICAL ANALYSIS

The making of a complete chemical analysis of a rock is a laborious operation that requires special equipment and much chemical knowledge and experience. It is also expensive. For ordinary practical purposes, and when the stone is not limestone or quartzite for use in metallurgy or chemical manufacture, such analysis is not required.

In the case of igneous rocks, it is quite important to determine the water, carbon dioxide and sulphur. The water and carbon

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[1] Hirschwald, J. Handbuch der Bautechnischen Gesteinsprüfung, Berlin, 1912, p. 146–47, 167–72.

dioxide afford a measure of the freshness of the rock, but should be supplemented by microscopic study. The sulphur establishes the relative proportions of the sulphides — pyrite, marcasite or chalcopyrite.

The presence of carbonates in igneous rocks can be quickly determined by powdering a little of the sample and treating with very dilute hydrochloric acid or equal amounts of acetic acid and water. If carbonates are present, bubbles will form around the powder and gradually rise to the surface.

PHYSICAL TESTS

The laboratory testing of stone is an attempt to ascertain the resistance which the material will offer to the various stresses that arise in engineering and architectural structures. The practice has but recently come into favor in this country, but it has been followed abroad for a longer time. The general interest now taken in the subject may be ascribed largely to the initiative of the engineering staffs connected with highway and other public improvements.

One of the first reports on quarry materials to give attention to their physical testing and to embody a fairly comprehensive series of results is Smock's "Building Stone in New York."[1] The data of the tests relate to specific gravity, absorption, the action of acids, change of temperature and the influence of heat.

It is well to note that the capacity of a rock to resist the many variations of strain can not be estimated by any single physical test. Crushing strength alone means little as to the quality of stone for use in street work or its probable behavior when placed in an arch. Moreover, physical tests of any kind do not fill the place of microscopic investigation of the mineral association and textures of rocks and their full value is attained only when they are combined with the results of study into all the general properties of the materials.

The most comprehensive work on the subject of testing of stone undoubtedly is Hirschwald's "Handbuch der Bautechnischen Gesteinsprüfung," which has already been referred to. The work is a scientific exposition of the subject based on actual results obtained by the use of various physical, chemical and microscopic methods of investigation. The volume was issued in 1912 so that

[1] N. Y. State Museum Bul. 10. 1890.

it can be said to represent the most modern practice, with special reference, of course, to German and continental methods.

The different physical tests are designed to yield information as to the following properties: specific gravity and weight; porosity; absorption; hardness and toughness; strength under compressive, transverse, tensile and shearing stresses; wear or abrasion; resistance to fire; and durability when exposed to frost, changes of temperature and other weathering influences. These will be briefly discussed in their order.

Specific gravity and weight. The specific gravity of any material is its weight compared with an equal volume of pure water. In the case of solid bodies like rocks that are insoluble in water, the determination is carried out by weighing the samples in air and then finding their weight when suspended in distilled water. The weight in air divided by the loss of weight in water is the specific gravity. The matter, however, is not quite so simple, owing to the fact that rocks are more or less porous and there is some trouble in securing moisture-free samples for the first weighing and complete saturation of the samples for the second. This can be accomplished, however, in the following manner: samples of cubical shape, weighing at least 40 or 50 gramms, are heated in an air bath at 110° C. until they show no further loss of moisture, when they are placed in a desiccator and allowed to cool. After weighing, they are immersed in distilled water which at first may be boiled to hasten the expulsion of air. They should be maintained under water for a period of from three to four days, when they will have reached a condition of practically complete saturation. They are then removed from the bath, their outer surfaces rapidly dried with blotting paper and then weighed. It will be found that determinations made in this way are fairly accurate, and there is less opportunity for error through faulty manipulation than by determining the gravity with the use of a picnometer or specific gravity bottle. It gains a further advantage in that the same samples and weights are useful in finding the porosity.

The weight of stone per cubic foot is usually determined by multiplying the specific gravity into the weight of a cubic foot of water, which is 62.4 pounds. This is sufficiently accurate for the closely textured rocks, but with porous sandstones a deduction must be made equivalent to the weight of the same rock required to fill the pore space. A more direct method is to weigh a cubic or rectangular piece of the rock of known volume after drying to constant weight. From that result, the weight per cubic foot is readily calculated.

Porosity. The determination of porosity is one of the most important physical tests. The pores of rocks admit moisture, and its expansion on freezing exerts such pressure as may lead to disruption of the material. The scaling of some sandstones when exposed to frost action is very noticeable. Furthermore, under equal conditions porosity affords some indication as to the resistance stones will offer to the solvent action of waters and vapors and to the penetration of smoke, dust and other discoloring agencies. It has been held by some writers that the porosity is an absolute measure of the durability of stone; but this is an overstatement of the matter, since the size of the pores and their relations to each other, that is, whether isolated or connected by capillary channels, has as much, if not more, influence than the absolute porosity.

The total pore space or porosity is readily calculated from the determinations for specific gravity, according to the method already described. The difference between the weights of the samples dry and saturated gives the amount of water absorbed in the pores. By multiplying this quantity by the specific gravity, we obtain an expression for the weight of rock required to fill the vacant pore space. This, added to the dry weight, gives the total weight the sample would have if there were no pore space. If the weight of rock required to fill the pores is then divided by the latter and the result multiplied by 100, we have the porosity expressed in percentage of the volume of the sample. This method devised by Buckley has been commonly followed in the reports on American building stones. It has been used in the determinations made in connection with the present report.

German testing laboratories measure the porosity somewhat differently by determining the specific gravity of the powdered rock and the so-called " Raumgewicht " or density of the stone inclusive of pores. The latter is found by dividing the weight of the sample expressed in grams by the volume in cubic centimeters. The difference of the two values divided by the specific gravity and the result multiplied by 100 gives what is called the coefficient of porosity.[1]

[1] Consult Hirschwald, " Handbuch der bautechnischen Gesteinsprüfung," p. 109–10.

Absorption. The absorption of a rock is the ratio between the weight of the absorbed water and the dry weight of the sample. It is determinable, therefore, from the same measurements that are used in finding the porosity. The weight of the absorbed water is divided by the weight of the dry stone; the result multiplied by 100 gives absorption as a percentage of the mass. The relation between porosity and absorption varies with the specific gravity of the stone, but the latter commonly amounts to about one-half of the former.

The ratio of absorption, any more than the porosity, does not afford an absolute index of the permeability of stone to water. Parks[1] has conducted an interesting experiment to test the permeability in samples having different porosities. Samples of rock 3 mm thick were cut at right angles to the bedding planes. Through these pieces water was forced under pressure of 15 pounds to the square inch and the amount of flow in one hour recorded. It was found that stones having less than 1 per cent of pore space were practically impermeable to water under that pressure. The results on some sedimentary rocks are as follows:

STONE	POROSITY PER CENT	PERMEABILITY: CU. CM OF WATER AN HOUR
Guelph limestone	15.883	90.5
Guelph limestone	14.62	155.1
Chazy limestone	17.517	2.25
Medina sandstone	10.44	2130
Niagara limestone	10.443	12.75
Beekmantown limestone	1.313	.72
Potsdam sandstone	4.947	1.75

Hardness and toughness. Hardness is a property of homogeneous materials like minerals by which they resist penetration. It lacks the same degree of definiteness when applied to rocks which are composed of various minerals and perhaps held together by some cementing substance of still different nature. In such conditions, it may be regarded as the resultant of the hardness of the various ingredients plus the bond between them.

There is no uniformity in the practice of determining hardness, which is an important feature of materials to be used in paving and street work generally. One method follows that in use for comparing the hardness of minerals and is based on the rate of penetration

[1] "Building and Ornamental Stones of Canada, Ottawa, 1912," v. 1, p. 61–62.

of a drill. The common practice in laboratories for the testing of roadstones is to subject a specimen of definite dimensions to the abrading action of a grinding disc. The loss of weight after the disc has revolved a certain number of times is a measure of the hardness. In the laboratories of the State Department of Highways at Albany, the test is carried out on a core of rock, 1 inch in diameter and 3 to 4 inches long, obtained with a diamond drill. The ends of the core are faced off and then the latter is weighed. One end is placed against a Dorry grinding machine, so as to bear with constant pressure upon the disc upon which quartz sand of standard quality and size is fed. The disc is revolved 500 revolutions at the rate of 2000 revolutions an hour, when the core is taken out, reversed end for end, and ground for another 500 revolutions. The loss in weight in grams is noted. One-third of this loss subtracted from 20 is the relative hardness. A hardness below 14 is considered soft, between 14 and 17 medium and above 17 high.

Toughness may be defined as the resistance to rupture from impact by a falling body. It differs from hardness in that it depends mainly upon the texture of the material, more especially the manner in which the components are interlocked. Fibrous aggregates like those of talc, serpentine and gypsum, though possessing little hardness, are very resistant to rupture, as shown by the difficulty in pulverizing such materials in a ball mill. Tests for toughness are commonly carried out on roadstones, but have less value for building materials. The method of testing toughness as adopted in the New York State Department of Highways is as follows:

> The toughness test is made by taking two core pieces one inch in diameter which have been obtained with the diamond drill, as was done for the hardness test. The ends of these core pieces are accurately and carefully smoothed off so as to form cylinders 1 inch in height. They are then placed on a firm, level bearing in an impact machine, securely clamped and subjected to blows through a one-kilogram weight. The first blow of the hammer is from a height of 1 centimeter. Each succeeding blow is from a height 1 centimeter greater than the preceding one. The number of blows, which equals the drop expressed in centimeters of the last blow required to break the core, is considered as the toughness of the stone. The toughness of the stone is represented by the average of the two core pieces broken. A toughness below 13 is considered low, between 13 and 19 medium and above 19 high.

Strength. The crushing strength is determined by applying a gradually increasing pressure upon a cube placed between two steel plates until the stone breaks down. It is usual to note also the pressure at which the first crack occurs. The value of the results depends upon the care used in preparing the cubes, which should be sawed, not dressed to size with the hammer, and also upon the relation of the faces of the cube to the structure of the stone in the quarry. In sedimentary rocks, the pressure should be applied at right angles to the bedding. In granites and other igneous rocks that have rift and grain, tests should be made upon three samples of each rock, so as to find the strength perpendicular respectively to the rift, grain and heading. Even with the greatest care in the selection of samples and their preparation, the tests will show wide variations in the crushing strength of rock from the same quarry. Nearly any quarry material, however, has sufficient strength to withstand any compressive force that is likely to develop in the walls of a building. Buckley states that a stone with a crushing strength of 5000 pounds to the square inch is sufficiently strong for any ordinary building.[1]

The transverse strength is determined on rectangular pieces which are supported at the ends on knife edges and subjected to a pressure in the middle from another knife edge. The test has some value for stone to be used in arches, lintels, and similar purposes.

Tensile strength is seldom determined on stone, although commonly tested in cements. It is equally, if not more important, however, than the compressive strength, as it measures the bonding power and gives some indication as to the behavior of stones under the internal stresses of contraction and expansion. Shearing strength is measured by the resistance the stone offers to forces tending to displace the particles with reference to each other. Tests for it are rarely made.

Wear or abrasion. The resistance to wear by abrasion may be said to be dependent upon the qualities of hardness and toughness. It is useful to determine such resistance in macadam and paving stones. The method employed in the State Department of Highways is to prepare with the aid of a breaking press, cubical samples of from 1¼ to 2½ inches diameter, of which 50 will approximate 5 kilograms in weight. The pieces are then washed, dried, and placed in a cast-iron cylinder, mounted at an angle of 30° with the axis of rotation, and revolved for 10,000 revolutions at the rate

[1] Building Stones of Wisconsin, p. 59.

of 2000 times an hour. The stone is then taken out, washed, dried and the weight of material less than one-sixteenth of an inch in size computed. The per cent of loss of the original weight is expressed by the French coefficient which is obtained by dividing 40 by the per cent of wear. Thus a stone which loses 4 per cent in weight during the test would show a coefficient of wear of 10. A coefficient of wear below 8 is considered low, between 8 and 13 medium, between 13 and 20 high and over 20 very high.

Resistance to fire. The resistance of stone to intense heat may be considered one of the important qualities in building stones that should be given consideration by the architect and builder, but which is very often neglected. Fires in cities work great damage upon stone structures. The test of extreme heat followed by sudden chilling from the play of water upon the surface is one that very few stones will pass through with strength and appearance unimpaired. There is, however, considerable variation among different building stones in respect to fire resistance, as may be observed in their condition after a large conflagration like that of Baltimore or San Francisco. Some buildings are completely ruined, so far as the possibility of making any use of the stone work for reconstruction; others are only damaged as to their exposed parts like the cornices and window openings; and some appear to be practically uninjured.

Intense heat causes both physical and chemical changes in stone. The most apparent effect is the spalling and cracking incident to unequal expansion between the outer and inner parts of the blocks. Stone has a very low capacity for transmitting heat; consequently, the interior may be still comparatively cool while the surface is intensely hot. This difference in temperature sets up a stress that disrupts the stone or causes the outer part to flake off in successive layers. The same process takes place in nature where changes of temperature are extreme; in the arid regions like the Great Basin, the warmth of the sun after a cool night causes the scaling of bare rock surfaces, but of course at a comparatively slow rate.

The disruption of rocks of complex mineral composition, such as granite, is probably traceable to some extent to the loosening of the bond between the ingredients through intergranular strain. Quartz, feldspar and mica each has its own rate of expansion which must produce a certain amount of differential thrust under rapid temperature changes. Further, most granites hold occluded liquids and gases in closed cavities which were imprisoned during the consolidation of the mass from its state of liquid fusion. These are mainly found in the quartz which is the last ingredient to separate out from an igneous magma. Under high temperature, they exert, no doubt, a heavy pressure upon the walls of the minute cavities and thus cooperate with the other influences in the work of disintegration.

From consideration of the physical characteristics, it would appear that the varieties of rock having a close, firmly interlocked fabric and simple mineral composition would prove the most resistant to fire. Among the igneous rocks, granite might naturally be expected to succumb more easily than a rock like syenite or anorthosite which is composed mainly of feldspar, and actual tests seem to bear out that inference. Some sandstones are very nearly fireproof and limestones and marbles generally bear up well until the heat is sufficient to effect crumbling through calcination. The temperature necessary to produce incipient calcination of small cubes of limestone, according to Buckley,[1] lies between 1000° and 2000° F. McCourt[2] states that tests on some New York limestones did not show calcination at 550° C. (1022° F.).

A temperature sufficient to cause flaking and cracking of granite, as well as sandstone and marble, may be attained in a fire that is confined to the contents of a single building. The State Capitol fire of March 29, 1911, which extended to only a part of the western wing of that building, played havoc with the granite columns and ornamental work, so that it was necessary to replace them wherever they came in direct contact with the flames. The columns were from Connecticut and Nova Scotia quarries. Some of the sandstone and marbles used in the interior work were cracked, but as a rule stood up better than the granite. The granite on the exterior of the building (a medium-grained gray stone from Maine) was injured to a minor extent, except in the lintels and cornices and other exposed parts, which were more or less cracked or disintegrated.

Exposure to fire may bring about more or less change of color, through oxidation of any ferrous iron compounds or the dehydration of limonite. It may also break down or expel some of the organic compounds which are coloring agents in limestones.

Tests for fire resistance are usually conducted on small samples of cubic shape, from one to four inches thick. The larger the samples, the more nearly will the results approach those produced on building materials in an actual conflagration.

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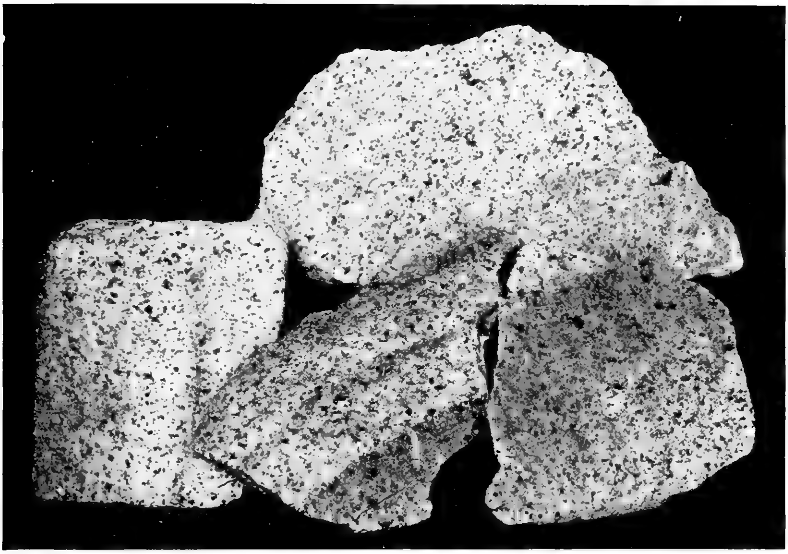
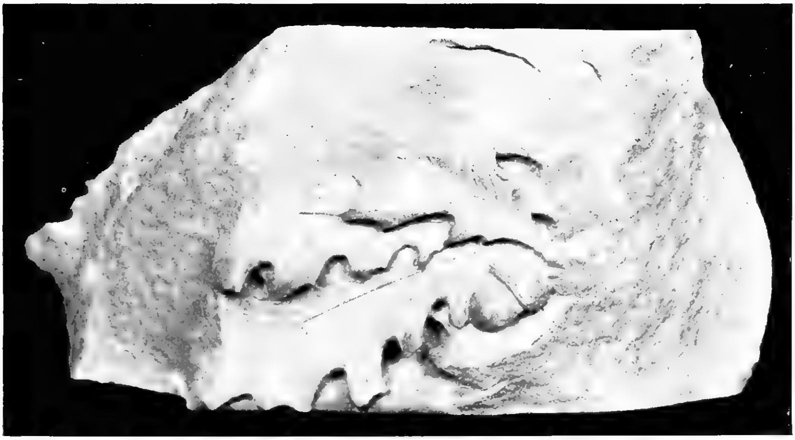
[1] *Op. cit.*, p. 385.

[2] Fire Tests on Some New York Building Stones. N. Y. State Mus. Bul. 100, p. 22. 1906.

Plate 4





Effects of fire upon building stone. Above are shown spalls of granite from a column, below a cracked and broken sandstone cap; both are from the State Capitol, Albany, after the fire of March 29, 1911.

McCourt,[1] who experimented with some of the principal building stones from local quarries, employed three-inch cubes, making, so far as the materials would allow, six tests on each sample. Four tests were performed in a Seger gas furnace in which one cube at a time was heated. The heat was applied gradually until a temperature of 550° C. was reached, this being maintained for half an hour. The cube was then taken out and allowed to cool in the air. A second sample was heated to the same temperature and then chilled suddenly by a stream of water. The third tube was treated in the same way as the first, except it was heated to 850°, and the fourth heated to 850° was chilled with water. Five tests were made with a gas blast to imitate, so far as practicable, the actual play of flame in a conflagration. On one sample, the blast operated for ten minutes, enveloping three sides in a steady stream; after cooling for five minutes, the cube again received the blast during ten minutes, after which it was cooled. The second cube was subjected to the flame for ten minutes and then a strong stream of water along with the blast for a period of five minutes. Then the water was turned off and the flame continued for another five minutes, after which, for five minutes more, the flame and water together were allowed to act on the sample. For the details for the tests, the reader should consult the paper itself. In brief, the results showed that all stones were fairly resistant to a temperature of 550° C. (1022° F.), and curiously, the granites showed up somewhat better than the others. At 850° C. (1562° F.), which probably represents the degree of heat reached in a conflagration, perhaps exceeding the temperature in some cases, all the stones were more or less injured, the amount of damage varying with the individual cubes. The granites and gneisses cracked and spalled. The sandstones parted along the bedding planes, a few developing cross-fractures. The limestones were little injured up to the point where calcination began, but after that they failed badly. The marbles developed cracks before the calcination temperature. The results, as pointed out by McCourt, were indicative of the effects of flame and water upon exposed stone work like cornices, lintels etc., rather than upon stone laid in walls which would suffer much less injury.

Action of frost. Structural stone that is exposed to the recurrent effects of freezing and thawing may suffer more or less damage therefrom in the course of time. The ability to resist this kind of weathering is to some extent measurable by porosity, since it is the

[1] *Op. cit.*

pressure exerted by the freezing of the included moisture that causes the damage. As already stated, however, neither the porosity nor the ratio of absorption can be regarded as an index of the resistance to such action under all conditions, since the character of the pore cavities exercises probably even more influence than their relative proportion.

Other things being equal, if the pores are sufficiently large and connected to permit the fairly rapid escape of the absorbed water, the stone will prove more resistant than one having an intimate network of fine or capillary pores.

The expansion of water in changing to solid ice amounts to one-tenth of its volume. It is, therefore, necessary that the pores should be filled to about nine-tenths of their capacity before the frost begins to become effective; otherwise, there will be room for the expansion to take place without exerting any pressure. In nature, the condition of saturation in stone is very rarely approached and it is difficultly attainable even with the methods employed in the laboratory for determining porosity. It is, therefore, the degree to which the pores of a stone can be filled under natural conditions that determines the resistance to frost. The experimental tests in which complete saturation is established by long-continued soaking or with the aid of a vacuum are too severe for practical use.

Hirschwald found that pieces of sandstone and granite removed from a building in Berlin at the end of December, about the beginning of freezing weather, and after a rainfall of 80 mm in the months of November and December, showed only a fraction of the moisture they were capable of absorbing. The specimens were taken from a height of 20 cm above and below the ground level. The samples of sandstone contained from one twenty-fourth to one twenty-eighth the amount of water they would hold after one hour's immersion. The granite from above ground level held about one-third and that from below the same quantity that the granite would absorb in one hour.

The quantity of water absorbed by stone under natural conditions divided by the amount the same stone requires for the entire filling of the pores is termed the saturation coefficient. The danger point is reached when the coefficient is .9, as with more than that proportion the water on freezing will expand and exert pressure upon the cavity walls. According to Hirschwald, who bases his conclusions on about twelve hundred tests of different stones, the practical limit may be taken at .8.

The method for determining frost resistance as described by that writer is to subject the samples after soaking to a temperature of — 15° C. for four hours. The sample is then thawed in water at 20° C. The operation is repeated twenty-five times after which it is examined for any weakening of strength or for fractures. The degree of saturation to which the samples are subjected at the beginning depends upon whether it is a matter of testing stones for use in dams or similar works submerged in water or for ordinary structures. In the former case, they are soaked for a period of 30 days. In testing architectural stones, they are placed in water for a period of from 2 to 13 hours, depending on their density.

In Smock's report are included the results of several tests on New York building stones. The samples weighing from 300 to 400 grams were saturated with water and subjected to alternate freezing and thawing seven times. All the granites and limestones passed the tests uninjured so far as noted; likewise the marbles, except one sample from Pleasantville; and the sandstones, with the exception of one sample from Oswego Falls. The two samples specified developed checks after repeated freezings.

Section 2

MAIN FEATURES OF THE GEOLOGY OF NEW YORK STATE

The physical features of our State as they now appear have their beginnings far back in the remote periods of geologic time. Among the rock formations underlying its surface are some of the oldest that are anywhere exposed on the American continent, possibly antedating the appearance of life, and at any rate so completely altered by the vicissitudes of the ages that they show no recognizable organic remains and few of their original physical structures. It is in those Precambric formations as represented in the Adirondacks and the southeastern Highlands that the earliest records of the physical development of our State are to be sought.

There is naturally much doubt about the conditions which prevailed in the remote periods of time included within the Precambric era. It would appear, however, that the continental land surface already existed in general outline in that era, although of course the area was not confined by the present bounds. Most of the Precambric formations now exposed are gathered in the north on the Canadian side of the boundary; the southern line of this central or nuclear area follows the St Lawrence river from the Gulf to the Great Lakes. But there are important extensions of this old land to the south of Lake Superior in Michigan, Wisconsin and Minnesota and also one considerable area farther east in the Adirondacks. The Hudson Highlands, a part of the Appalachian highland, also have Precambric strata along their main axis.

The lowest formations of this old land surface which are largely of igneous character may be separately classed in the Archean system. Upon their exposed parts the agencies of construction and destruction were operative probably in a similar manner and with equal energy as now. From the erosional waste, extensive deposits of limestone, shale and sandstone were accumulated at a later period beneath the waters which encroached on the land. These old sediments, aside from their highly metamorphosed states, are not essentially different from those accumulated during succeeding ages. Volcanic forces no doubt had their part in the development of the structure, but all vestiges of the ancient lava flows have been swept away and only the underlying channels are now in evidence with their fillings of diabase and porphyry.

In the Adirondack region no basement or crystalline complex assignable to the Archean period has been discovered. The oldest igneous rocks apparently have intrusive relations with the sediments whenever they come in contact with the latter, and consequently the first recognizable elements are of clastic origin, classed as Grenville or Algonkian. These consist of crystalline limestones or marbles, banded and foliated gneisses, hornblende and mica schists, and quartzites. They are interfolded with the early igneous gneisses and have been invaded and injected by all the Precambric intrusions. They have consequently a patchy distribution, though forming belts of rather wide extent on the northwestern side. They bear no recognizable life remains and the only evidence that life existed at the time is the abundance of carbon in the form of carbonates and graphite. The more important quarry materials of Grenville age are the limestones which yield building and monumental marbles and are sources of high-grade limes.

The deep-seated igneous rocks consist of granites (both gneissoid and massive), syenite, gabbro and anorthosite. Among the granites may be recognized at least two classes based on their relative age; an older, much compressed, finely granular variety that has been squeezed out and elongated into beltlike bodies, and a younger, massive, coarser type that occurs in the form of bathyliths and bosses. In the earlier series may be present parts of the Archean basement if they are anywhere existent. The younger granites are most useful for quarry purposes. The Adirondack syenite has sometimes a reddish color, like that of much of the granite into which it grades in places, but the characteristic and by far the most widely developed variety is a green augite syenite, usually with the original textures and structures well preserved. There are, however, crushed and more or less foliated types of the green syenite. The gabbros are found in dikes and bosses as separate intrusions and as border phases of the anorthosite with which there appears to be complete gradation. The anorthosite constitutes an immense bathylith in the east central section of the Adirondacks, the largest intrusion of the whole region and, except for a few areas of Grenville which were probably engulfed during its approach to the surface, a practically unbroken mass. The several periods of igneous activity to which these deep-seated masses may be assigned were probably times of crustal upheaval and metamorphism, at least the varied conditions of foliation, crushing and recrystallization which are exhibited by the intrusions seem to be significant of repeated modifications by dynamic agencies. As the last manifestation of igneous action in the Precambric era came intrusions of diabase, reaching the surface no doubt and forming lavas, but now found only in the filled-up channels or dikes below the old outlets. There are countless numbers of these dikes in the eastern and northern Adirondacks. They are all younger than the last period of general metamorphism and have remained practically unchanged, except by surface weathering.

The Highlands region, according to the more recent investigations which have been carried on chiefly by Berkey,[1] presents quite an array of Precambric rocks quite similar to those already enumerated for the Adirondacks, except that here the acid or more siliceous types greatly predominate in the igneous complex. The main element in the geology of the central area is a group of gneisses, which are known to be composite, though they have not been definitely classified. They include the oldest formations and such contrasting representatives as the massive granite gneiss of Storm King in the northern section and the foliated banded Fordham gneiss which has sedimentary affinities and is widely distributed in Westchester county. There is also a considerable development of mixed types, probably an involved aggregate of igneous and sedimentary derivatives. Small bands of crystalline limestone and quartzite are found in the central Highlands and, with the older sedimentary gneisses, constitute a series which is placed by Berkey in the Grenville. There seems to be no recognizable parts of the Archean in this section. The Precambric intrusives are mostly granites, with a few syenites and diorites. Igneous activities did not cease, however, with the close of the Precambric, as was the case in the Adirondacks, but continued as late at least as Siluric times.

The older gneisses in the region are succeeded by a group of metamorphosed sedimentary formations including crystalline limestones, schists and quartzites. These find strong representation in the southern section where the limestones have some importance for building marbles and lime-burning. While they are certainly younger than the gneisses of the central Highlands, their precise place and relations are not altogether clear. It is possible, as has been suggested by Merrill, that they are the more thoroughly metamorphosed equivalents of the Hudson river beds to the north of the Highlands, in which case they belong to the Cambric and

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[1] See specially " Structure and Stratigraphic Features of the Basal Gneisses of the Highlands." N. Y. State Mus. Bul. 107, 1907.

Lower Siluric systems. Berkey would separate them into an earlier Precambric and a later or Paleozoic group, of which the Precambric group is made up of the Lowerre quartzite, Inwood limestone and Manhattan schist — the members that belong more strictly to the Highlands region. The later, or Paleozoic formations, are the Poughquag quartzite, Wappinger limestone and Hudson River slates; they occur only in small down-faulted areas in the Highlands, but have a very widespread distribution north of there, particularly the slates which outcrop along the whole central Hudson valley. The Yonkers gneiss may be mentioned in connection with the Precambric, as an igneous derivative, later than the Fordham gneiss with which it is in contact. It occurs in a long narrow belt and in isolated bodies in southern Westchester county. According to the earlier interpretation, as advanced by Merrill, its age is later than the Hudson River slates. The rock has considerable local importance as a building stone.

The period of Precambric history, so far as it can be formulated from the rocks of the New York areas, began, therefore, with the accumulation of sediments composed of quartzose, argillaceous and calcareous materials that are collectively known as the Grenville series. They must have been derived from some preexisting rocks which, if still found anywhere, represent the Archean or basal complex of the Lake Superior and Canadian regions, but so far no vestiges of this older surface have been identified. Subsequent to their deposition, there was a long lapse of time in which the forces of upheaval, metamorphism and igneous activity were manifested at intervals on a tremendous scale. The sediments were compressed, plicated and completely recrystallized. Their lower parts were invaded and broken up by deep-seated intrusions, representing several different periods and rock varieties. Volcanic energy was also displayed and led no doubt to extensive accumulations of lavas and other igneous materials at the surface. By these agencies, the land areas must have acquired a very considerable elevation, probably with a rugged mountainous topography to which the surface of the present day is hardly comparable as to altitude and massive features. Upon such land surfaces erosion would be very active and powerful in its results. Destruction thus was in progress while the upbuilding went on; while in the latter part of the Precambric time there was a long period of continued erosion without compensation by uplift. The effects of this were the removal of an immense but unknown thickness of rock from the upper zone, leaving the deeper buried parts exposed much as they are today and greatly reducing the inequalities of contour. The waste thus derived was washed toward the sea to form the first of the normal fossiliferous rocks.

The Paleozoic era began with the deposition of sediments upon the uneven surface of the Precambric crystalline rocks. It appears that with the close of the Precambric era the land which had remained above water since Grenville time underwent a gradual subsidence, bringing the outer borders within reach of the sea. With its submergence there were formed stratified deposits which contain the earliest records of life that are at all well defined and abundant. The lowest members, belonging to the Lower and Middle Cambric groups, are not so widely developed in this State as the Upper or Saratogian group in which lies the Potsdam sandstone. This is exposed in a rather broad but variable belt on the north and northwestern sides of the Adirondacks where it still preserves a horizontal position on the eroded edges of the Precambric rocks. It is also present in the Lake Champlain valley and on the southeastern edge of the Adirondacks as broken areas of a once continuous belt. In its characteristic form it is a quartzite, and a very hard, durable stone. The lowermost Cambric beds include the Poughquag quartzite in southern Dutchess county and the Georgia slates found in the metamorphic area along the New England boundary. Besides the Potsdam quartzite, the Saratogian group also contains some limestones of which the better known member, the Little Falls dolomite, is quite extensively developed in the Mohawk valley and is the basis of quarry operations. The limestones are usually impure, representing a transition from the sandstones to the high-grade limestones above.

With the continuance of the submergence and consequent deepening of the waters, the deposition of the Champlainic or Lower Siluric beds was begun without any break or interruption to mark the line of division with the Cambric group. The more important representatives in the lower part consist of limestones, of which the Tribes Hill, and Beekmantown and Chazy members may be named. The first has little importance areally, but the Beekmantown (inclusive of the middle and upper beds as earlier defined) is quite widely distributed in the Champlain valley. The Chazy is found in the same region from Saratoga county north to the Canadian border; it is one of the purest calcium limestones in the State. The subsidence of the land surface continued and the waters encroached more and more upon it. This provided opportunity for the deposition of the Mohawkian (Trenton) group of limestones, the most widespread and the thickest of the calcareous sediments. Among the individual members are included the Lowville, Black River and Trenton beds in the order of sequence. In the lower section they are heavily bedded and quite pure, but become shaly toward the top. They have importance for building stone, cement and lime manufacture. They are often highly fossiliferous. They occur in the Champlain valley, but are more prominent on the Vermont side than on the New York shores. Continuous with the Vermont area, a belt extends across Washington county into Warren and Saratoga counties. Another large belt begins in the Mohawk valley near Little Falls and extends northwesterly with increasing width to the St Lawrence river, overlapping onto the Adirondack crystalline rocks. The upper limestone beds of the Trenton pass gradually into shales, indicating an influx of mud. This condition lasted through the Cincinnatian period when the Utica, Frankfort and Pulaski shales of central New York were laid down. In the Hudson valley and eastward there was a marked preponderance of shales over limestones in the sedimentation throughout the whole Lower Siluric period; the great mass of shales which has come to be known as the Hudson River formation began to be deposited in fact as early as Cambric time.

At the close of the Lower Siluric period, the Taconic disturbance interrupted sedimentation in the area along the Hudson river and upraised that section into dry land. The agencies of compression and metamorphism which were forceful enough to produce a highly folded and more or less metamorphosed condition in the shales, limestones and sandstones of the east did not extend their effects very far to the west. The Adirondack and Mohawk valley formations were not changed noticeably or disturbed from their normal position, though possibly there was some faulting which initiated the great meridional breaks along the eastern and southern Adirondacks. In the Highlands regions the effects may have been much more pronounced, as indicated by the intrusion of the great boss of the Cortland rocks. Other deep-seated invasions may be represented by the serpentine masses of Staten Island and Rye and by the Harrison diorite, though these are possibly of earlier date.

The Ontario or Upper Siluric period was continuous with the Lower Siluric as regards sedimentation in the interior of the State, though on the borders of the Taconic land surface the two series of formations are separated by a strong erosional unconformity. The Upper Siluric was a time of shallow water accumulations. In the basal members, as represented by the Oswego and Medina sandstones and the Oneida conglomerate, the materials consisted largely of the coarser detritus washed down by rapid streams and deposited close to the shores. The Medina, however, contains much shale near the top. The Niagara formations are mainly shale (Clinton and Rochester) and dolomite (Lockport and Guelph). During Clinton time, the waters were probably rather shoal with off-shore bars sheltering them from the sea as indicated by the precipitation of iron ores along with sandstones, shales and limestones. The formations up to the Guelph had been deposited along a nearly east-west shore line that lay to the south of the Canadian and Adirondack highlands; they are now found in belt-like areas extending across the central and western parts of the State. In the Cayugan period the zone of sedimentation extended into southeastern New York on the shore of the Appalachian protaxis. The Salina shales formed at the opening of the period are characterized by the deposits of rock salt and gypsum which probably resulted from the evaporation of the sea waters in confined basins. The succeeding formations include the Cobleskill, Rondout and Manlius limestones. The Medina sandstone at the base of the Upper Siluric is one of the more important building stones in the State and the various limestones named find utilization for lime, cement or constructional purposes.

The change to Devonic time was very gradual and no break occurred in the sedimentation. In the first or Helderbergian period the deposits were mainly calcareous and restricted to the central and eastern parts. The Oriskanian period began with limestones, but afterward the Oriskany sandstone, a very persistent, chiefly arenaceous, formation was deposited. To Ulsterian time belongs the Onondaga limestone, one of the very important calcareous formations, largely quarried in the central and western sections. With the Erian period began the accumulation of the great series of Devonic shales and sandstones that spread over the whole southern plateau section of the State from the Catskills and Helderbergs west to the Pennsylvania border. The sandstone members are the bluestone quarried for flagging, curbing and building stone and range in age from the Hamilton in the Erian period to the Chemung at the top of the Devonic. In the Senecan period occurred an interval of limestone deposition in the central part represented by the Tully limestone.

The Carbonic era introduced at the start no marked variation in the sedimentation. The representatives include shales and sandstones with conglomerate at the top; the last being the equivalent of a part of the Pottsville conglomerate in Pennsylvania. There are no coal beds anywhere exposed and the conditions requisite for their production did not become very general until after the last of the local beds were laid down. The Carbonic strata are limited to a small area in the extreme southwestern section. The long lapse of time that ensued to the close of the Carbonic and all of the following Permic era find no record in the strata of New York State.

The Appalachian revolution brought Paleozoic time to an end and marked the final emergence of practically the whole mainland area of New York from the sea. The disturbance resulted in a broad uplift in the central and western parts of the State, but no change in the relative attitude of the formations. In the southeast, however, along the main axis it developed in some folding as shown by the Shawangunk mountains.

Mesozoic time was marked by only slight additions to the geological structure of the State. The Newark shales of late Triassic age, which occur in Rockland and Richmond counties were probably formed in estuaries along the coast. During and after their deposition, igneous activity was manifested by the intrusion of diabase which, in places, reached the surface. The Palisades consist of the exposed edge of a diabase sill intruded along shale and sandstone beds of Newark age. With the last, or Cretacic, period of Cenozoic time came the deposition of the older clays of Staten Island and Long Island.

During the Cenozoic interval there were small accumulations of Tertiary clays in the same areas. The most important event of the era in its influence upon the local geology occurred in the Quatenary period with the change of climate that brought on an ice invasion. This advanced from north to south and spread over the whole State, overriding even the higher mountains. The ice eroded away the loose materials accumulated by weathering and also transported immense quantities of rock which it plucked from the bared surfaces. The contours were rounded off and the land covered with a mantle of clay and boulders (till), the transported materials being also heaped up in the form of hills and ridges which are known as moraines and drumlins. The drainage was also obstructed or remodeled; some large lakes occupied the main river valleys for a time, as in the Hudson valley. The main effect of the ice upon the rock surface was to remove the evidences of the long preceding period of weathering; consequently the rock outcrops appear much fresher than they do in the unglaciated territory to the south of New York.

Section 3

THE CRYSTALLINE SILICATE ROCKS

PRELIMINARY DISCUSSION AND DEFINITION OF TERMS

Before entering upon the description of the different quarry materials, it may be well to explain that the classification of rocks into three principal groups — igneous, sedimentary and metamorphic — which has been followed hitherto scarcely serves the purpose of an economic classification that is based on general quarry features and uses. From a practical standpoint, there is no line of division to be drawn between many metamorphic gneisses and schists and the igneous rocks, since they may have the same applications and present the same problems in quarrying and dressing. It is customary, therefore, to include the metamorphosed silicate rocks which are useful for structural stones with the massive igneous types, and that practice will be followed here.

The other metamorphic rocks include slates which are placed in a separate division, marbles which with some nonmetamorphic limestones are also separately described, and quartzites which from an economic point of view belong in the class of sandstones.

The crystalline silicate rocks of the Adirondacks and southeastern New York embrace a variety of individual types such as granite in the strict sense, syenite, diorite, anorthosite, gabbro of different kinds, diabase, and an assemblage of gneisses and schists that includes both igneous and sedimentary derivatives of varied mineral composition.

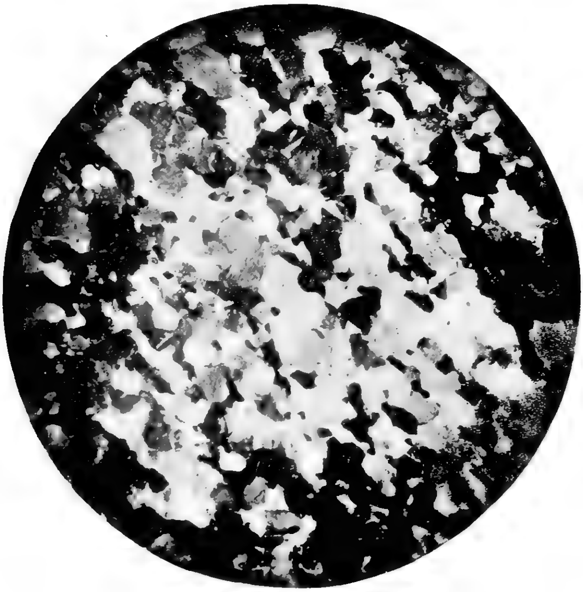
GRANITE

As an architectural stone, granite outranks the other igneous rocks of the State, which is true also wherever the crystalline silicate rocks are exploited. Its prominence is due in part to its relatively widespread occurrence, but largely to the combination of qualities in regard to color, uniformity and ease of extraction and dressing which is less often found in the other stones. The prevalent taste for light-colored stone in buildings has much to do with its general favor.

Although quarrymen and builders use the term granite rather indiscriminately to designate almost any of the silicate rocks that have been named, it probably belongs to a single rock series of igneous origin which is characterized in composition by the presence of potash, feldspar and quartz. These two minerals always predominate, but are often accompanied by others in greater

Plate 5

Photomicrograph of granite gneiss, Little Falls. Large particles are quartz and the rest mainly feldspar. Enlarged 22 times.



Photomicrograph of Yonkers granite. The components are quartz, feldspar and mica. Enlarged 22 times.

or less quantity, especially plagioclase, which may share importance with the potash feldspar, and by mica, hornblende or, rarely, pyroxene. The potash feldspar is either microcline or orthoclase, the former being the more common. Mica occurs in two forms — the white or transparent muscovite and the black biotite; usually both are present, but if one alone occurs, it is more often biotite. Hornblende is a rather common ingredient of local granites in which it replaces the mica wholly or in part. Pyroxene, which resembles hornblende in appearance when seen in the hand specimen, is restricted to a few types which are related to the syenites.

Besides the more important or *essential* ingredients named, granites usually contain a number of others in very small amount which may be called *accessory* constituents. Such are apatite, zircon, rutile, magnetite, pyrite, fluorite, tourmaline and garnet. There may be also various *secondary* minerals which have been derived by chemical alteration from some of the original constituents; thus sericite, kaolin and calcite result from the alteration of feldspar, and chlorite, serpentine, epidote and iron oxides result from the dark iron-magnesia minerals.

The chemical composition of various local granites will be found under the quarry localities elsewhere in this volume.

The texture of granite is usually even-grained, with the feldspar and quartz in particles of nearly the same magnitude. There is no regularity, however, as to the size of the particles in granites from different localities, and there is likely to be more or less variation in that respect in different parts of the same mass. A granite may be said to have a *coarse* texture if the crystals of quartz or feldspar average over 10 mm or 0.4 inch in diameter; *medium* if the crystals range between 10 mm and 5 mm; and *fine* if they are less than 5 mm. In the very fine sorts, the crystals average under 1 mm. The same rule for classifying textures will be applied to the other quarry stones.

The specific gravity of granite varies from about 2.5 to 2.75. This corresponds to a weight, without allowance for porosity, of from 156 to 172 pounds to the cubic foot. The average weight is about 165 pounds, and a cubic yard in the quarry may be taken roundly as equal to 4500 pounds.

Granites are white, gray or pink in color, with occasional examples showing a bright or deep red. The feldspar is the main coloring agent, as it predominates over the other ingredients, but the general color effect is really a combination of the individual colors of the minerals. Muscovite and quartz are colorless or translucent white, and the iron-bearing ingredients (biotite, hornblende and pyroxene) are usually black. By alteration to sericite or kaolin, the feldspar loses its naturally brilliant luster and becomes opaque and earthy. The coloration of some granites arises from infiltration of iron compounds in sufficient amount to overcome the color values of the silicates and impart their own effects. This is well instanced by the yellow Mohegan granite from near Peekskill, the beautiful color of which is traceable to a little limonite that has found its way into the stone by means of the capillary pores. That the color is not due to local alteration of the minerals is very apparent from examination of thin sections which show the only iron-bearing silicate (biotite) to be quite fresh in most of the stone and only occasionally is a local deepening of the color observable about that mineral. At the surface the biotite shows some alteration with the production of chlorite, but there is very little iron discharged in the process, altogether too little for the amount of limonite distributed through the body of the rock. Apparently the iron has come from above, probably introduced in solution as a ferrous compound to be subsequently oxidized to limonite.

SYENITE AND ANORTHOSITE

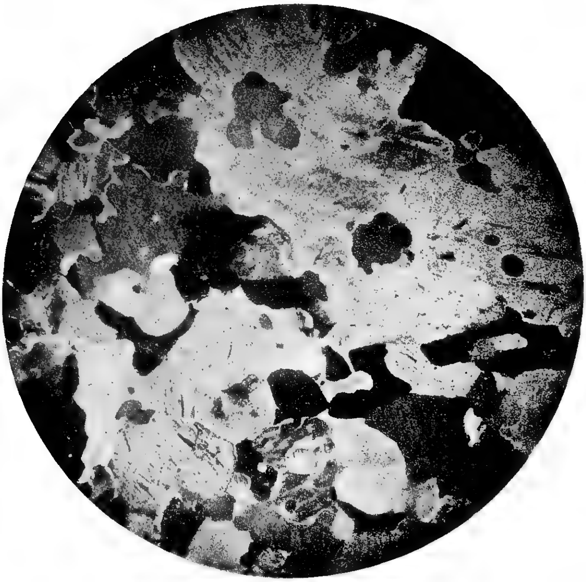
Syenite and anorthosite belong to separate rock series but, from a practical standpoint, are much alike. Both consist of feldspar as the essential ingredient, with accessory hornblende, biotite, pyroxene and magnetite. In syenite, the feldspar is an alkali variety, either microcline or orthoclase, or an intergrowth of one of these with albite, known as microperthite. Anorthosite, however, consists of a basic plagioclase, usually labradorite, with one or more of the iron-bearing silicates and usually ilmenite in the place of magnetite.

Their structure is mostly even-granular and compact. As to strength and durability, they are nowise inferior to the granites, if not exceeding them in some elements which make for permanency. In specific gravity they average a little higher than the latter and range from about 2.65 to 2.90, with 2.75 perhaps as a mean value. Their weight is accordingly around 175 pounds to the cubic foot.

They are not so abundantly distributed as granite, but where they occur they constitute equally large bodies, sometimes forming bosses and bathyliths of great size.

The color of syenite, and of anorthosite as well, is darker than that of average granites. Green and blue tones are not rare, and the luster from the feldspar is often very brilliant, making the

Plate 6



Photomicrograph of green syenite, Ausable Forks. Mostly feldspar, with some quartz and pyroxene. Enlarged 22 times.

Photomicrograph of anorthosite, Split Rock. The main component is labradorite which appears stratiated. Enlarged 22 times.

stone serviceable for polished and decorative work. The deep green of the Adirondack syenite is very characteristic. Anorthosite is either gray or dark green, the latter being characteristic of the feldspar in its original state, while gray is peculiar to the crushed and recrystallized varieties. The uncrushed feldspar shows the blue iridescence common to labradorite which adds much to the beauty of polished samples.

There are no peculiarities in the weathering of the two rocks, and they yield the same decomposition products named under granite. On the whole, syenite appears more resistant to frost action than the latter, at least it seldom breaks up into a granular aggregate which not infrequently marks the outcrop of granite bodies. As to the durability of anorthosite, little can be said from the point of practical experience since it has not been used very long for outdoor work. The rock, in place, shows little change on the surface. At Augur lake, near Keeseville, there are vertical cliffs of anorthosite which have been directly exposed to the weather ever since the glacial period; these show a bleached film not more than one-fourth of an inch thick coating the surface, but no stain or softening. This appears a favorable indication of its permanency under atmospheric conditions.

DIORITE

The name diorite is used to denote a rock containing plagioclase and hornblende as essential minerals. The plagioclase is nearer the albite than the anorthite end of the series, including such varieties as oligoclase and andesine; the hornblende is the same kind that accompanies syenite or granite and is usually plentiful. The color, consequently, is rather dark, with the grayish tones predominating. Some diorites contain considerable biotite which, if it gains ascendency over the hornblende, makes a mica-diorite as distinguished from the hornblende type which is simply a diorite. The composition of the diorite is intermediate between that of granites on one side and the gabbros on the other, and it might be expected to find gradation toward either series, through the appearance of certain characteristic minerals. The mingling of quartz and alkali feldspar makes a rather common variation from the type, leading to the class of granodiorites which may be described equally well as basic granites.

The diorites are not common rocks in this State. There are no large areas of typical massive diorite; some of the gneisses in the Adirondacks are related to diorites in mineral composition, having perhaps originated from such rocks, though now changed to the gneissoid somewhat altered forms which are commonly termed greenstones. The characteristic green hue of these altered types is due to the formation of a chloritic mineral out of the hornblende or biotite.

Granodiorite is represented by the great area of so-called Harrison diorite in Westchester county and by smaller masses in both the Adirondacks and southeastern New York.

The physical characters of diorites are not very different from those described under granites; in the case of granodiorites the resemblances are very close. They are a little darker in color, never appearing in reddish tones, but always grayish or greenish; average around 2.8 or 2.9 in specific gravity, corresponding to a mean of about 180 pounds to the cubic foot; and are useful for all purposes to which granites are put, except they are less readily polished, owing to the presence of so much hornblende and mica.

GABBRO

Gabbro is composed typically of pyroxene and plagioclase, the latter being one of the more basic varieties—labradorite or anorthite. Unlike the rocks previously described, it usually contains more of the iron-bearing silicates than of feldspathic minerals and hence the color is very dark, ranging from grayish or greenish gray to black. The pyroxene includes both orthorhombic and monoclinic varieties which very frequently show partial alteration to hornblende. Olivine is a common and at times an important ingredient; its presence is denoted by a prefix to the rock named, for example olivine-gabbro.

Gabbros are peculiarly subject to fluctuations in mineral composition through a relative gain in the proportion of one or another of the common minerals, a variation caused by some process of differentiation during the period of intrusion and consolidation. By increase of the feldspar and corresponding shrinkage in the pyroxene there results the rock already described as anorthosite. This is really, therefore, a gabbroic type and not related directly to syenite. The predominance of pyroxene leads to pyroxenite, in which feldspar is very sparsely if at all represented. Olivine, with subordinate amounts of feldspar and pyroxene, forms a peridotite. The principal iron ore in gabbro is ilmenite which may be sufficiently concentrated locally to form fairly pure masses of considerable body.

The gabbros, owing to their content of the iron-magnesia silicates, are rather heavy, averaging from 2.8 to over 3 in specific gravity. Their weight ranges from 175 to 200 pounds to the cubic

Plate 7

Photomicrograph of gabbro, Port Henry. Constituents are pyroxene, feldspar and magnetite.

Photomicrograph of diabase, Fort Ann. Lath-shaped crystals of feldspar in a groundmass of pyroxene. Enlarged 22 times.

foot. In fresh condition they are fairly hard and exceedingly tough, but lose these qualities rapidly if decomposed by atmospheric weathering. Their decomposition is sometimes hastened by the presence of sulphides, which are likely to be abundant in places, more so than in acid rocks. The characteristic alteration product of the more basic gabbros is serpentine.

Gabbros find little employment for architectural work, owing to their somber appearance. They are used to some extent for decorative and monumental purposes under the trade name of "black granite." Quarries in Maine, Minnesota and North Carolina have supplied such stone, but very little has come from the large gabbro areas of New York. The main developments in this State have been for the supply of crushed stone for macadam and concrete, for which purposes the fine-grained dense sorts may be considered equal to the best trap.

The limited use of the stone for general purposes is partly due, no doubt, to the expense of dressing it. The basic rocks seldom show any rift or grain structure, but break with a curved fracture without reference to direction.

DIABASE OR TRAP

Trap is a popular term for the dark, fine-grained igneous rocks that occur in intrusive sheets and dikes. It is thus not a distinct rock type, but may include diabase, basalt and any of the basic intrusions which have a sheetlike form. In New York State, the name is equivalent practically to diabase, an intrusive containing lime-soda feldspar and pyroxene as essential ingredients, with subordinate amphibole, olivine and pyroxene. The composition thus is very similar to that of gabbro, but the appearance of the rock is quite characteristic, owing to the manner in which the minerals are distributed. The feldspar forms laths or rectangular rods that inclose the pyroxene, olivine and amphibole in their irregular interspaces like a network. This gives a firmly interlocked texture which insures a high degree of toughness and resistance to abrasion.

Diabase is almost black on rock face and polished surfaces. Like gabbros, it finds limited employment for structural stone. Its specific gravity is about 2.9 and the weight around 180 pounds to the cubic foot. Its fine grain promotes evenness of wear, so that with its other qualities it is exceptionally well adapted for road material and concrete in all cases that involve heavy duty. Some examples make a good black granite, as shown by specimens of the polished Palisades stone in the State Museum. Ordinarily it has no rift or grain and hence is difficult to reduce into dimension blocks; in some quarries, however, the stone splits readily enough to be converted into Belgian blocks.

The main area of diabase in this State is the Palisades intrusion, a long north-south sill or sheet lying within shales and sandstones of Triassic age and extending from Haverstraw to near Richmond on Staten Island. The sill is from 300 to 800 feet thick. Its exposed eastern edge with its vertical joint systems, forms the precipitous cliffs of the Palisades. This area has been a prolific source of crushed stone which has been used in road-making and concrete throughout the lower Hudson valley. There are countless numbers of diabase dikes in the Adirondacks, particularly in the northern and eastern sections, but they are mostly small, averaging only a foot or two thick, occasionally reaching 20 or 30 feet, and in one instance at Little Falls, nearly 100 feet.

GNEISS AND SCHIST

Gneiss and schist are general terms applied to the metamorphic silicate rocks whose original characters of texture, structure and, not infrequently, mineral composition have been more or less completely changed under influences of compression, heat and chemical agencies. Their chief structural peculiarity arises from a parallel arrangement of the minerals, the light and dark components being segregated in lines or bands which simulate the bedded structure of sedimentary rocks. The planes of segregation, as in the case of bedded structure, mark the directions of actual or potential parting; the schists, particularly, have a very well-developed capacity for splitting which resembles slaty cleavage in its perfection.

The gneisses of more massive type are suitable for general construction purposes but ordinarily do not lend themselves to decorative uses on account of their lack of uniform texture and appearance, both of which vary with the direction of view. Such kinds are mainly derived from granite and other massive igneous rocks. Under the influence of powerful compressive forces, the originals have been squeezed and stretched, bringing the scaly and elongated minerals into parallel alignment and crushing the rest into granular aggregates. The change may be not altogether a physical one, but is generally accompanied by the development of new minerals and more or less recrystallization of the mass. If the massive rocks originally had a coarse or porphyritic appearance, very often there will remain shattered but still distinct crystal aggregates of the porphyritic mineral in the midst of the finer material. This is particularly observed in the metamorphic products of feldspathic rocks like granite and syenite which often show lenticular remnants of the original porphyritic feldspars and are known as "augen" gneisses.

Gneisses have all the variations in composition that are found in the igneous rocks. Those of granitic composition are naturally the most important for quarry purposes. Many of the granite masses show gneissic phases on their borders, as is the case also of the syenites, gabbros etc., the parallel lamination arising from differential compression during consolidation or later. In some places gneisses are formed by the injection of igneous material into a hornblende or mica schist that is itself a modified sediment. There are many such occurrences in the Adirondacks in localities where the Grenville schists have been invaded by granite; the latter apparently in its cooling has given off solutions charged with mineral materials which penetrated into the schist for long distances and converted it into a firm, hard gneiss. The so-called granite from Horicon is really an injected mica schist, with porphyritic feldspars and quartz derived from igneous sources. The Manhattan schist and Fordham gneiss as represented in most of the quarry localities contain a large proportion of granitic material interleaving or commingled with the ingredients from sedimentary sources, and it is by reason of this injection that they are serviceable quarry stones.

SERPENTINE

The mineral serpentine is formed almost entirely by alteration of other ferro-magnesian silicates, chiefly pyroxene and olivine. The latter minerals, as has been noted already, are important constituents of the basic igneous rocks of the gabbro family, some members of which are made up wholly of them. Their alteration, which is a process of hydration largely, with the separation of more or less lime as calcite and of some of the iron as iron oxides, takes place readily under atmospheric weathering and leads to the formation of extensive bodies of rock serpentine that has some use for architectural and decorative purposes.

There are several areas of serpentine in southeastern New York, of which the largest is on Staten Island, covering all the higher central part of that island. Other bodies are found on Manhattan island (now concealed), at New Rochelle and Rye. The rock in these places has little economic importance, owing to its badly jointed and fractured condition. Serpentine is one of the softer minerals and on that account the rock can not be applied to general constructional purposes, but finds a market chiefly as an ornamental material by reason of its lustrous green color and of the striking pattern produced by the blotches or veinings of iron ores and calcite.

Besides this kind of serpentine, mention may be made of serpentinous marbles or ophicalcites which are derived from impure sedimentary limestones. In the metamorphism of the limestones, pyroxene is formed which later changes over to serpentine, giving a mottled or spotted effect of green on a white body of calcite. Such serpentinous marbles occur in the eastern Adirondacks and have been used to a limited extent for monumental and interior decorative work.

PEGMATITE

Pegmatite is really a member of the granite series, being a coarse-grained intrusive composed of feldspar, quartz and mica. It has little value for structural purposes which granite serves, and in its mode of occurrence and origin differs somewhat from the ordinary representatives of that series. It is found in dikes with fairly regular tabular form, but also occurs in irregular winding veins and occasionally in masses that show a lenticular or rounded outcrop like bosses of the finer grained igneous rocks. The latter type may attain very large proportions, that is a thousand feet or more in diameter, while the dikes seldom exceed 40 or 50 feet in thickness and for the most part are under 10 feet.

The mineralogy of pegmatites is of much interest on account of the variety and fine crystallizations of the species that accompany them. The important species, however, are the same as those described as essential constituents of granite. The quartz is commonly white, gray or pink, occurring in crystals or massive, and ranging from a few inches to several feet in diameter. It is also more or less intergrown with the feldspar, sometimes in a peculiar way which is known as "graphic granite." The feldspar includes the alkali varieties like microcline, orthoclase and albite, with usually more or less of lime-soda feldspar of oligoclase or andesine nature. Individual crystals sometimes measure 5 or 6 feet long. Both the quartz and feldspar are valuable where they can be obtained in condition of fair purity and uncontaminated by iron; their principal use is in pottery, but they serve many other purposes. The mica of pegmatite belongs to both the lighter iron-free sorts like muscovite and phlogopite and the dark variety biotite; it builds sheets and thicker plates that attain a size up to 2 or 3 feet across. Its occurrence in pegmatite is the source of commercial mica, but the mineral has to be free of inclusions and checks to be of much value, which is very rarely the case in any of the Adirondack pegmatites.

In addition to quartz, feldspar and mica, there are a great many minerals that occur in more or less abundance in the local pegmatites. Some of the commoner ones are tourmaline, beryl, garnet, amphibole, magnetite, pyrite, apatite, zircon, titanite, lepidolite, chlorite, epidote and calcite; of rare occurrence are monazite, xenotime, autunite, dumortierite, molybdenite and allanite. The crystals of tourmaline and beryl may weigh many pounds.

Pegmatites are quite variable in their composition, changing much more rapidly in that respect than granite. The proportions of feldspar and quartz fluctuate through all possible ranges, as may be seen in almost any of the larger bodies like those at Crown Point and Bedford, for example. A mass of practically solid feldspar in one place gives way in a short distance to one of quartz or to a mixture of the two minerals. These fluctuations take place horizontally and vertically and often are the cause of much inconvenience if they do not seriously affect the progress of quarrying, especially where it is aimed to secure a uniformity of products. In many quarries this feature seems to have been ignored at first, and the results of work consequently have not corresponded to expectations. There is need of careful investigation to determine the character and uniformity of the materials in each locality which should precede actual development. Bosses and large dikes of pegmatite extend downward into the earth for indefinite distances, usually much farther than they can be followed in open quarry operations. The lenses and veins are much less persistent, often pinching out abruptly.

Pegmatite is associated with many of the granite areas in the Adirondacks and southeastern New York. In most of the granite quarries small irregular masses of the material are encountered, in some with such frequency as to impair the value of the product. In the larger occurrences the pegmatite may be left as a wall in the quarry. The irregular bodies which grade over into the granites are apparently not intrusive in the latter, but have resulted from crystallization of the magma in place, the coarse texture being due to the local presence of abundant water vapor and other mineralizing agencies. The pegmatite is probably the last part of the mass to crystallize and represents the residue of magmatic material with an excess of the solvents or mineralizers squeezed out by the consolidation of the surrounding granite.

The larger bodies in the form of dikes or bosses represent real intrusions of much later age than the country rock. They occur in any kind of country rock, be it gneiss, schist or limestone. Consequently they are sharply delimited on the borders, without any gradation as is observed in the segregated bodies. They are offshoots of some granite mass which may be quite distant or not at all in evidence at the surface. All through the western Adirondacks, but particularly in St Lawrence county, dikes, veins and bosses of pegmatite occur intersecting the older gneisses, and schists, with only here and there a body of granite in evidence that may be regarded as a source of the materials. It is very probable that much of this region is underlain by a great granite bathylith of which the exposed granites and pegmatites are offshoots into the overlying rocks. The larger pegmatite bodies are often conspicuous features in the topography, as they are very resistant to erosion and tend to form knobs and ridges. They are consequently most frequently encountered on the higher ground and when uncovered may be visible for long distances, on account of their white color.

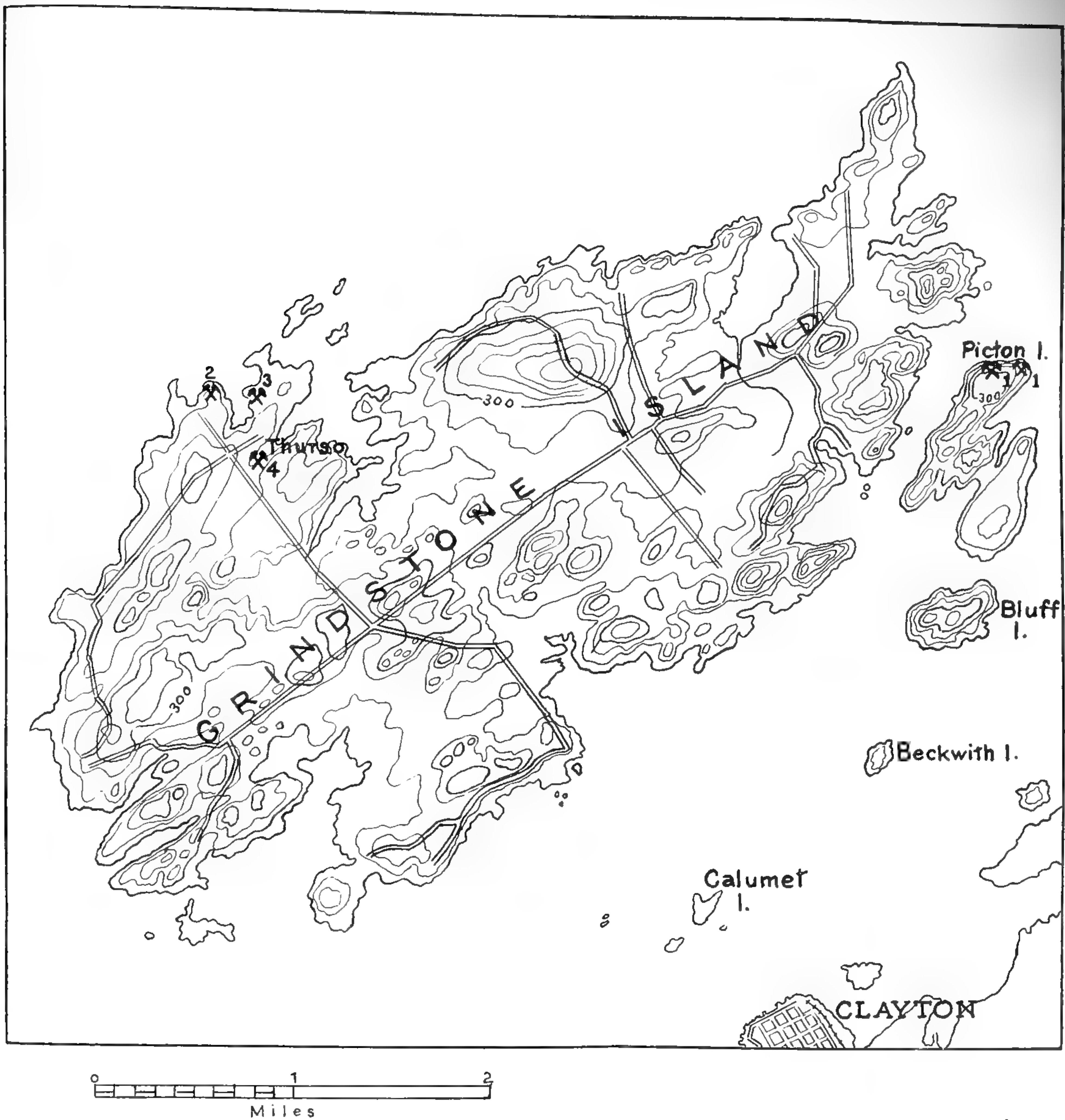


Fig. 6 Map of the St Lawrence river granite quarries. 1, Picton island; 2, Forsythe; 3, Kelly; 4, Webster quarries.

Section 4

FIELD OCCURRENCE OF THE GRANITES, GNEISSES, TRAPS, ETC.

THE ST LAWRENCE RIVER GRANITES

Granite and granitic gneiss are exposed on several of the larger islands in the St Lawrence river, particularly in the stretch from Clayton to Alexandria Bay and over a considerable area on the adjacent mainland. They are outlying representatives of the Adirondack crystallines, though separated from the main area of the latter by an interval in which the surface formations consist mainly of undisturbed Paleozoic sediments. These rocks undoubtedly covered the whole region at one time, but have been eroded away here and there so as to expose the underlying Precambric basement. In contrast with the Adirondacks, the Precambric area along the St Lawrence presents very little relief, for the most part being less than 100 feet above the river and much of it is quite flat. Suitable quarry sites are therefore not so common in this section as in the interior highland where rocks of similar or identical character occur, but the region is favored by the facilities for water transportation which give access to the important markets on the St Lawrence and Great Lakes at very low rates.

The most valuable quarry material in this section is the red granite of Grindstone, Picton and Wellesley islands, a product with which the name Thousand Island granite is popularly associated. It has had a fairly large sale for building and monumental purposes, taking rank with the best of the red granites from American quarries. In general it is a bright red, coarsely textured rock; but medium-grained and fine-grained varities also occur. It has a thoroughly massive appearance, and the grain is very uniform so far as relates to the product of a single quarry.

The present exposures of this granite have been traced on the geological maps prepared by Cushing and others for the report on the "Geology of the Thousand Islands Region."[1] The granite extends from the central part of Wellesley island, where it is in contact with the older granitic gneiss series, to the western limits of that island, and reappears on Grindstone, of which it constitutes

[1] N. Y. State Mus. Bul. 145, 1910. The red granite lies mainly within the Grindstone quadrangle.

the larger part. It also outcrops on the smaller islands between Wellesley and Grindstone, including Murray, Picton, and Bluff islands.

GRINDSTONE ISLAND GRANITE AREA

Grindstone is an irregular, deeply indented island, about 5 miles long and 2 miles wide, lying nearly midway in the river, directly opposite Clayton. It is included in the Grindstone quadrangle of the United States Geological Survey. The island is low and thinly soiled, though it affords some good grazing and agricultural land. The principal settlement is Thurso on the north shore and near the western end.

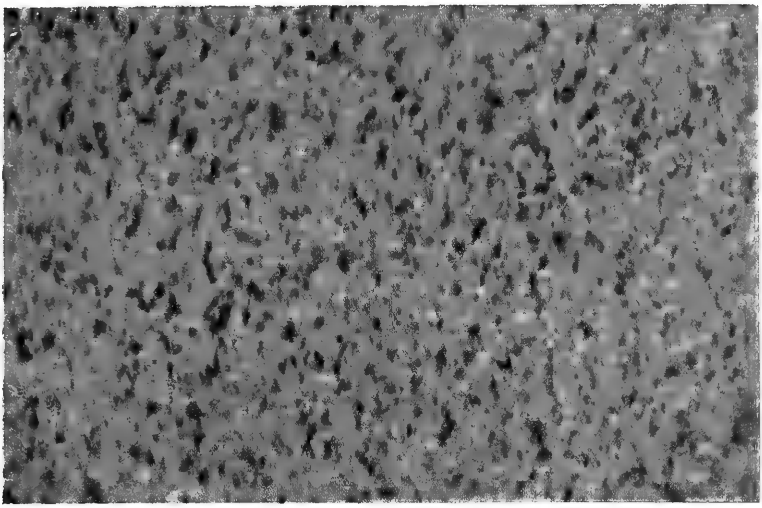
As shown on the geological map by Cushing and Smyth, the red granite occupies all the eastern and northern part of the island, but on the south and west gives way to the older Grenville and Laurentian gneiss series, into which, however, it sends offshoots that in places are of considerable magnitude. It is also not unmixed with these rocks, as inclusions of the Grenville schist and quartzite and of the lighter Laurentian granite are found within the interior of the red granite. These inclusions appear, however, to be arranged in definite belts and are not so generally distributed as to give trouble in quarry operations, if a little care is exercised in the selection of a site. Aside from these larger inclusions the granite shows a fair degree of uniformity. Occasional "knots" of darker color are noticeable in some of the quarries and seem to be in the nature of segregations.

The principal quarry workings are in the vicinity of Thurso. For the last few years none of the quarries have been actively operated, though some stone is taken out occasionally on orders for building and monumental work. The period of greatest activity dates back fully fifteen years. In Smock's report of 1888 it is stated that quarries had been opened at more than twenty different places on the island and that three large quarries were then in operation.

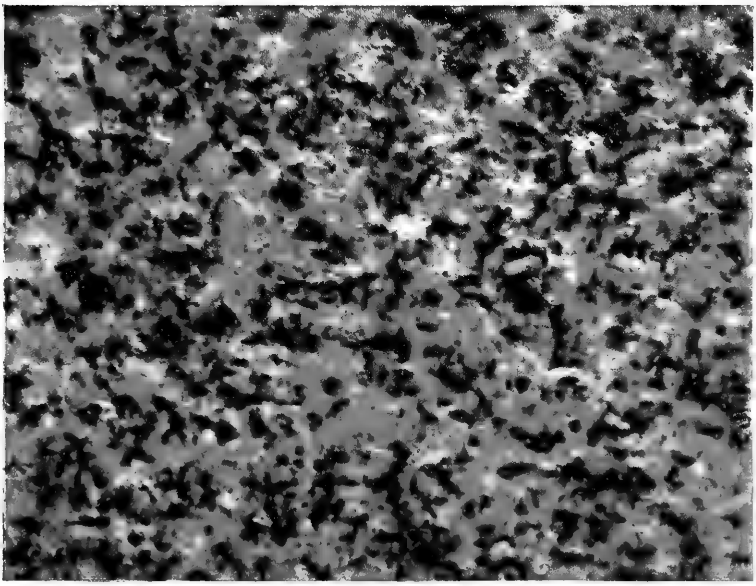
General character and composition. The Grindstone Island granite usually has a coarse texture which is imparted by the abundant large feldspar individuals. It has, nevertheless, excellent polishing qualities, giving a fine and lustrous surface. The color is bright red for the polished surfaces but lighter on the rock face and very light on hammered work. The stone is therefore suitable for buildings in which a medium color effect is desired and at the same time is well adapted for monumental or interior work.

The mineral composition of the granite is somewhat variable

Plate 8



Pink granite. Picton Island, St. Lawrence river



Red granite. Picton Island, St. Lawrence river

according to locality, but in general it may be said that red feldspar constitutes about three-fourths of the whole, while quartz and biotite are next in abundance. The feldspar consists of microcline, microperthite, and oligoclase and shows some alteration. The quartz has a bluish or opaque white color. Along with the biotite there is some chlorite, evidently from alteration, and hornblende. The minor ingredients include magnetite, titanite, pyrite, zircon and apatite. The feldspar shows incipient decay, but is not materially softened.

The following chemical analysis is taken from Cushing's "Geology of the Thousand Islands Region." It is based on a sample from a quarry described as 1 mile southeast of Grindstone, perhaps referring to the Gordon quarry. The analysis is by E. W. Morley.

SiO_2	66.59
Al_2O_3	14.54
Fe_2O_3	2.42
FeO	2.43
MgO	1.18
CaO	2.15
Na_2O	3.08
K_2O	5.62
H_2O	.46
TiO_2	.81
P_2O_5	.40
Cl	.03
F	.06
S	.08
MnO	.23
BaO	.17
	100.25

Laboratory tests. Acording to Smock, a representative specimen of the granite showed a specific gravity of 2.713, equivalent to a weight of 169 pounds to the cubic foot. The absorption was 1.55 per cent of water. When subjected to a dilute solution of sulphuric acid, the loss was .13 per cent. No apparent change was caused by freezing and thawing, but exposure to a temperature of 1200°–1400° F. caused vitrification, destruction of color and impaired the strength.

A more elaborate test of the fire-resisting qualities of the granite was carried out by Mr W. E. McCourt. Two cubes tested to 550° C. with slow cooling remained unchanged, but one developed a few small cracks when rapidly cooled from that temperature. Cracks appeared in the cubes when heated to 850°, and under the flame and water test the granite was badly broken as was the case with all the cubes of igneous rocks that were subjected to that test.

The absorption of 1.55 per cent as given by Smock seems to be erroneous, perhaps due to the shifting of the decimal point. So large a ratio is seldom found in any granite. Physical tests of the granites by the writer gave the following values: specific gravity 2.71; ratio of absorption .171 per cent; pore space .462 per cent. In his "Building and Ornamental Stones of Canada," Parks includes the following data for the Kingston granite which apparently is almost identical in composition with the Grindstone granite; specific gravity 2.68; ratio of absorption .119 per cent; pore space .319 per cent; crushing strength 30,421 pounds a square inch.

Kelly quarry

Most of the stone shipped from the island in recent years has come from the Kelly quarry. This is also known as the Chicago Granite Company's quarry. It was opened about 1883 and worked by that company for several years. The present owner is H. B. Kelly of Clayton. The quarry lies on the southern and western slopes of a hill which fronts the little bay reaching southward toward Thurso. It is opened in two benches with a total height of about 75 feet and a length of over 200 feet. The rock has a rather coarse grain and is thoroughly massive. The only defect is the presence of rounded inclusions, or knots, of darker, finer crystalline rock which cause some waste in the quarrying of dimension stone. The jointing is not particularly well defined or regular. The principal courses are N. 75° E. and north-south, with less plainly marked series N. 35° E. and N. 50° W. The joints are widely spaced and permit the quarrying of blocks of large size. Sheeting is absent though there is an imperfect division along a plane which dips 15° or so to the north.

The present equipment includes one 40-foot derrick. The shipping dock is a few hundred feet north of the quarry and connected by a tramway. The quarry lands compose about 5 acres.

Paving blocks were the principal product made by the Chicago Granite Company. They were shipped chiefly to cities on the Great Lakes. Under the present ownership, monumental and building stock are quarried on a small scale. Several buildings along the St Lawrence have been constructed of this granite.

Forsythe quarry

The Forsythe Granite and Marble Company of Montreal operated at one time a quarry just north of Thurso and across the bay from the Kelly quarry. The shore on the west side of the bay rises abruptly 50 feet or more above the water, admitting of a good face directly at the shore line. The quarries extend north and south for about 200 feet. The rock is a little darker on the average than the granite of the Kelly quarry, but otherwise is very similar. The joints are even more widely spaced and indefinite. The more persistent courses are N. 45° W. and N. 40° E. The grain runs parallel with the latter. Blocks can be obtained of size limited only by the means of handling. The presence of inclusions of darker color is the principal defect. There is a little pyrite noticeable in some of the rock, but it is too small in amount to exert any detrimental effect in the durability or color of the stone. This is apparent in the freshness of the rock at the surface.

The granite at this quarry shows two varieties of texture, the one being characterized by coarse feldspar crystals of from 10 to 15 mm diameter and the other by medium-sized crystals of approximately 5 mm diameter. The former found employment for monumental and building stone and the latter for paving blocks.

The quarry is probably the same as that described by Smock under the name of the Thousand Island Granite Company, and active at the time of his report. The quarry was opened about 1880. The product in the early years was mostly paving blocks and was shipped to western cities. Building and monumental stone were also shipped in quantity to Montreal.

The Forsythe Granite and Marble Company, the last to operate the quarry, ceased work over ten years ago. There is no equipment of value remaining on the property. The shipping dock is directly at the quarry. The quarry is now owned by Miss Jennie Forsythe of Montreal.

A sample of the polished granite from this locality is shown in the large columns that adorn the Senate Chamber of the New York State Capitol at Albany. These are said to have been quarried from near the surface.

Other quarries near Thurso

On the farm of W. L. Webster about one-half of a mile east of Thurso is a ledge of red granite, once worked by White and O'Brien. This quarry face is about 200 feet long and 20 feet high. The joint courses are well defined and run N. 60° E. and N. 30° W. There is a fairly developed sheeting which dips 15° S. or nearly parallel to the slope, and facilitates extraction of the blocks. This stone is a little darker and more finely textured than at the other quarries visited, due to the increased percentage of the biotite and hornblende.

The quarry formerly worked by Gordon and Turcotte lies a little south of Thurso. It is perhaps the one described by Smock as situated about half a mile from the northwest side of the island, and known as the Gordon quarry. This was then operated by the International Granite Company of Montreal. Gordon and Turcotte ceased work about twelve years ago.

The Potter quarry, now owned by H. B. Kelly, lies about a mile southwest of Thurso and yields both red granite and a darker colored rock which is perhaps related to the Adirondack syenite but which was not seen in place. The latter stone is used for monumental work. The quarry has not been developed to any extent. The ledge is about 75 feet high and the quarry lands include 10 acres.

THE PICTON ISLAND AREA

The Picton Island Red Granite Company

The characteristic Thousand Island red granite is obtained at present in quantity only from Picton island, which yields medium-grained to fine-grained varieties as compared with the prevailing coarse granite of Grindstone island. Picton island lies about 3 miles north of Clayton, between Grindstone and Wellesley islands; it is called Robbins island on the United States Geological Survey map, though known locally by the former name. The quarries are on the northern end of the island, where the ledges rising directly from the shore line afford a face from 50 to 75 feet high, almost at the water's edge. There is little stripping or other preparation required, and the stone is loaded directly on boats from the quarries for shipment to river and lake ports. Rail shipments are made from Clayton, where the company owns docks and yards close to the railroad.

The Picton Island granite is a part of the same mass which outcrops over most of Grindstone Island and the southern end of Wellesley island. It is a closely textured, sound stone of attractive color, taking a lustrous polish and well suited for building and monumental work. Two varieties, medium-grained and fine-grained are obtained, the former having a bright red body flecked with black, and the latter a uniform pink tint in which there is little but the coloration of the feldspar noticeable. The pink granite finds special favor for monumental purposes.

The company has two quarries in operation, of which the more northerly has been mainly worked and has yielded most of the stone of medium grain. The face here is about 300 feet long and 75 feet high. The vertical joints are rather widely spaced and run N. 45° E. and N. 35° W. The bed joints dip into the hill at an angle of 15° or more, causing some difficulty in loosening the blocks. Material of any size can be obtained. A small dressing and polishing works have been provided for turning out finished material. The granite had a well-marked rift and grain, so that excellent paving blocks can be obtained from the waste, but this product yields little profit at present owing to the competition which has arisen from the quarries in the south with their cheaper labor.

The more southerly quarry is in process of development. It has a face about 150 feet long and 50 feet high with a slope which will afford 25 feet or more additional height. The principal product is pink granite, though there is some red, medium-grained granite associated with it. About 10 or 15 feet of the surface rock is discolored by sap and has to be stripped before marketable material is obtained. The jointing here is irregular, with no predominant directions noticeable.

A third quarry is situated between the others, but was not worked at the time of inspection.

The company has a very complete equipment and can furnish rough and cut stone in almost any size and quantity. Some of the structures for which this stone has been used include the new portion of the American Museum of Natural History in New York, the National Bank Building in Clayton and the Maryland Museum Building in Baltimore (polished columns). The red granite suitable for polishing brings about $1.25 a cubic foot and the pink granite from $2 to $3 a cubic foot.

General observations. The color effect of the red granite is very similar to that of the Grindstone Island granite. The polished surface is bright red. The rock face and hammered surfaces are lighter than the polished and give a pleasing warm tone when seen in structures. The contrast between hammered and polished work, as exhibited in monuments, is marked.

The pink granite is considerably lighter than the red and, owing to its fine texture, appears to be of almost uniform body. When tooled the color is pinkish white, and letters and designs stand out prominently from the polished surface. The stone is especially valuable for monuments.

Mineral and chemical composition. The Picton Island granite is essentially a mixture of feldspar, quartz and biotite, with no marked differences as regards composition between the red and pink varieties. The textures are even and thoroughly massive. The red or medium-grained variety is composed of particles averaging 5 mm in diameter and the fine-grained of particles averaging from 1 to 2 mm. The coloration is due to the feldspar ingredients which contain minute inclusions of hematite, magnetite, hornblende, garnet, muscovite, titanite, apatite and pyrite are present in small amounts. The pyrite is mostly limited to the joint surfaces and is so sparingly distributed as to exert no appreciable effect upon the durability and permanency of color of the granite.

The following chemical analysis by W. S. Hall of the Massachusetts Institute of Technology is abstracted from a circular issued by the Picton Island Red Granite Company:

SiO_2	69.20
Al_2O_3	13.80
Fe_2O_3	5.28
CaO	1.51
MgO	.77
K_2O, Na_2O	8.80
S	.04
H_2O and loss	.60
	100.00

The composition is normal for granite, with the exception of the iron which is a little higher perhaps than is usual in most granites. This is explained by the rather abundant magnetite, in which form the iron can exert no detrimental effect. Although the potash and soda are not separated in the analysis, the former probably predominates as the feldspar is mostly microcline and orthoclase with subordinate plagioclase. Treatment with acetic acid failed to give any reaction for carbonates.

Physical tests. According to information furnished by the company, the granite has a specific gravity of 2.653. A cubic foot accordingly weighs 165.81 pounds, which is about the average for eastern granites. The crushing strength, as determined in a cube taken from the quarries when first opened, is 16,500 pounds a square inch. An absorption test on a 4-inch cube dried to constant weight and immersed in water for five days showed .023 grams of water absorbed for each square inch of surface.

Specimens of the medium-grained and fine-grained granites from these quarries were submitted for testing to the bureau of research, State Department of Highways with the following results:

	Medium-grained	Fine-grained
Specific gravity	2.655	2.64
Absorption, pounds a cubic foot	.06	.13
Hardness	18.8	18.9
Toughness	12.	13.5

ALEXANDRIA BAY AREA

An exposure of granite or granitic gneiss around Alexandria Bay has been of some importance in the quarry industry of the St Lawrence river region. It has furnished little building or monumental stone, but is chiefly valuable for paving material and rough work.

The granite differs markedly in appearance from the granite quarried on Grindstone and Picton islands, having usually a finer grain, lighter color and a texture that in places is distinctly gneissoid. The occurrence is described by Cushing under the name of the Alexandria bathylith and is placed by him in the Laurentian gneiss group, older than the characteristic massive granite of the neighboring islands. The fine grain, as well as the gneissoid appearance which it exhibits in some places, is a secondary feature superinduced by regional compression; occasional uncrushed remnants of larger crystals (mainly feldspar) are still in evidence. The composition is that of a typical granite, with feldspar, quartz and mica as the principal minerals, ranking in the order given.

The granite extends for several miles north and south of Alexandria Bay along the river. Few ledges suitable for quarry sites occur as the country is generally flat and the higher ground often is mantled by Potsdam sandstone which rests in horizontal beds upon the granite. Much of the rock, also, carries inclusions of darker color and is seamed with quartz and pegmatite.

Quarry of J. Leopold & Company

The principal quarry in the Alexandria granite is situated about one-half of a mile south of Alexandria Bay and belongs to J. Leopold & Company of New York. A knob of the granite rises 100 feet or more above the river, forming the most conspicuous elevation in the vicinity. The bare rock is exposed on all sides of the knob which has a diameter in a northeast-southwest line of about one-fourth of a mile. A little bay sets in close to its base and forms a natural harbor accessible to river boats, which afford the only means of shipment. The main workings are on the east side where there is a cut 200 feet long. Smaller openings have been made on the top and north side.

The granite is well jointed, the main courses being N. 30° W. and N. 60° E. An indefinite sheeted structure appears in places. The structure and situation facilitate quarry operations and the only drawback is incident to the somewhat variable character of the stone which unfits much of it for anything but rough work. Two shades of granite appear in the quarries, one having a light gray color and the other a pinkish tint. Both varieties have the same composition and texture.

Microscopic examination. The appearance of the rock under the microscope is that of an originally rather coarse granite which has become finely textured through crushing and recrystallization. The process has not effected in this instance any noticeable parallel alignment of the minerals, but they show a compact arrangement conducive to strength.

The mineral composition indicates a biotite-muscovite granite of normal character. The feldspar is mainly of the alkali kind represented by microcline, microperthite and orthoclase supplemented by more or less lime-soda feldspar which appears to be oligoclase. It carries quartz inclusions and has a broken corroded appearance. Ferric oxide distributed along the fracture and cleavage planes of the feldspar is the coloring agent in the pink granite. The micas have only small representation and there is little magnetite or other accessory minerals.

Physical and chemical tests. In response to a request, Messrs J. Leopold & Company contributed the following data relative to physical tests of the granite which were made by the division of tests, United States Department of Agriculture, in Washington. The specific gravity is 2.65, corresponding to a weight of 165 pounds a cubic foot. Three cubes approximately 3 inches on a side were tested. Cubes no. 1 and no. 3 showed a strength of 17,780 pounds and 17,570 pounds respectively, for each square inch of cross section, or 20,860 and 22,220 pounds respectively for each square inch of bearing surface. Cube no. 2 resisted crushing to the breaking power of the machine.

The bureau of research, State Department of Highways, in its report for 1910 includes two tests of the Alexandria Bay granite, as follows:

	No. 1	No. 2
Specific gravity	2.64	2.64
Weight, pounds a cubic foot	165	165
Absorption, pounds a cubic foot	.17	.11
Abrasion, French coefficient	20.	17.4
Hardness	18.5	18.5
Toughness	8.	10.

A chemical analysis of the Alexandria granite, which is given in the Geology of the Thousand Islands Region, may be safely used in reference to the product of this quarry. The locality of the sample is given as one-fourth of a mile south of Alexandria Bay, thus in close vicinity to the quarry. The analyst is E. W. Morley.

SiO_2	73.10
Al_2O_3	14.29
Fe_2O_3	1.04
FeO	1.04
MgO	.53
CaO	1.18
Na_2O	3.08
K_2O	5.36
H_2O	.61
TiO_2	.18
P_2O_5	.03
Cl	.03
F	.02
S	.02
MnO	.07
	100.58

GRANITIC ROCKS IN THE WESTERN ADIRONDACKS

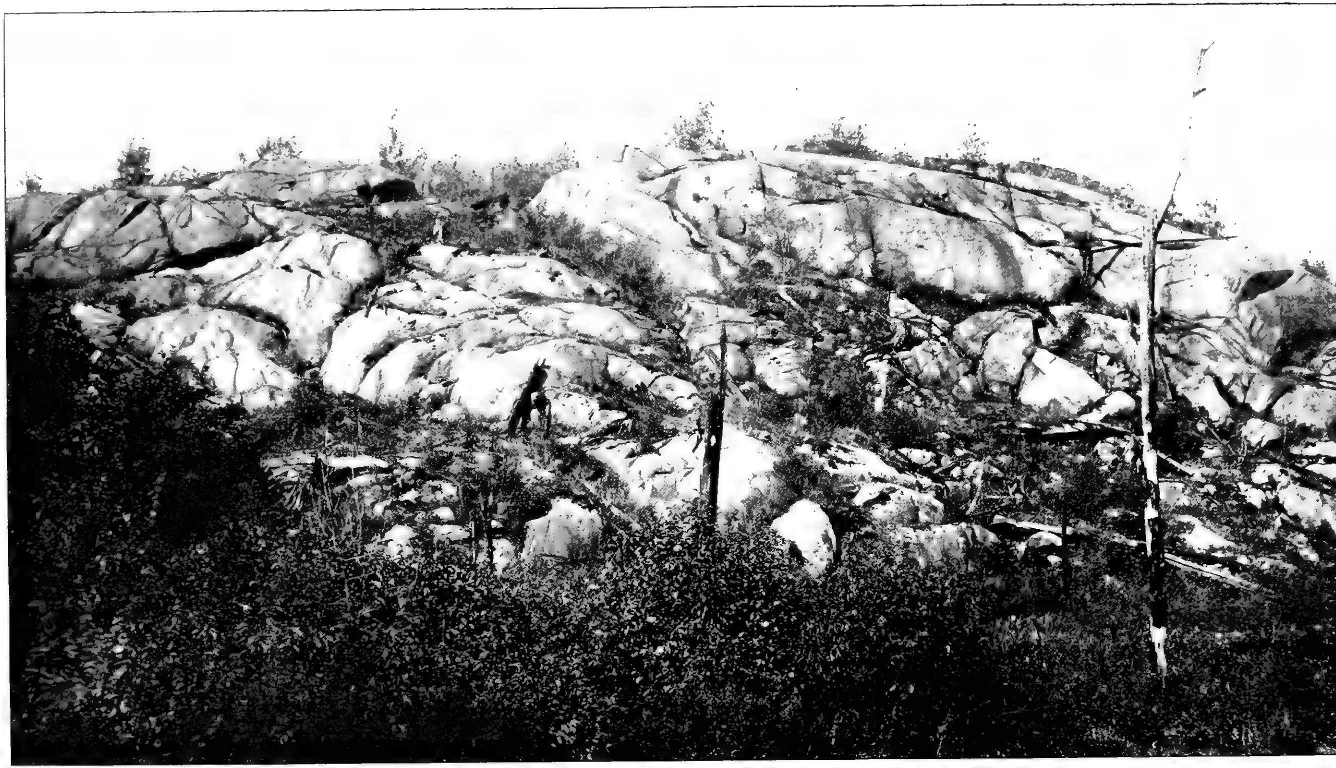
The western section of the Adirondack region, within the boundaries of St Lawrence and Lewis counties, is a complex of gneisses, schists, crystalline limestones and igneous intrusions, affording a considerable variety of quarry materials that are but little utilized. The only quarry developments of any importance in fact are based on the crystalline limestones which occur in belts, principally on the outer edge of the area. From these limestones are obtained excellent grades of building and monumental marble, of which the Gouverneur marble is the best example, as well as material for lime, furnace flux and road construction. The silicate rocks have received meager attention from an economic standpoint, the only development consisting of temporary and small-scale operations to supply local needs in the way of road metal or foundation stone.

In its topography the region is a plateau which slopes to the west and northwest, the surface broken by ridges and hills of inconsiderable altitude. The elevation of the interior ranges from about 1500 to 2000 feet, while the outer border where the crystalline formations disappear beneath the Paleozoic sediments lies for the most part between the approximate limits of 400 and 700 feet, but is somewhat higher than that on the south. The interior is largely wilderness and accessible only in restricted districts where one or two branch railroads have been extended eastward from the main lines which skirt the borders. Of these, the Carthage & Adirondack Railroad belonging to the New York Central system is the more important and runs from Carthage at the contact of the Paleozoic strata with the Precambric complex in a direction north of east across the central part of the highland as far as Newton Falls near the outlet of Cranberry lake. The few small settlements that exist in the interior are mainly dependent upon lumbering and the summer visitor for support. There is little local demand for building material of permanent nature.

Of the crystalline formations the gneisses and schists are most prominent, but massive rocks occur in several rather extensive areas. Granite, syenite and gabbro are the principal representatives of the igneous rocks. They constitute dikes, stocks, and larger irregular bodies that may be called bathyliths, all Precambric in age though widely separated no doubt in the intervals of intrusion. The term "massive" is hardly applicable to their general field appearance since they often pass by insensible gradations from such condition into gneissoid and schistose phases, scarcely distinguishable from some of the country formations which are made up of an unresolved complex of gneisses and schists with the more characteristic members of the sedimentary or Grenville series, the latter including quartzose, mica and hornblende schists, amphibolites, graphite schists, quartzites and crystalline limestones.

The massive granites of this region have for the most part decided colors, ranging from pink to dark red in the different occurrences, while the very light and gray shades are relatively uncommon. They are generally rather coarse in grain, but finer sorts occur as local modifications of the coarse rocks or in separate intrusions. The predominant reddish color is imparted by the feldspar of which the prevailing variety is microcline. Hornblende and biotite (both

Plate 9



Glaciated knob of red granite on Carthage and Adirondack Railroad, near Jayville

are usually present) constitute the dark ingredients most in evidence, but magnetite plays a more important part in the composition than usual in such acid rocks.

These red granites are perhaps the most available resource in the way of quarry material for general construction purposes within the interior of the western Adirondacks. They have a very wide distribution, with their gneissoid modifications covering a considerable but as yet undetermined area. In many places they do not show the uniformity of appearance or other qualities essential to architectural stone, particularly where the intrusions are small and, in the case of the larger bodies, along the contact zones which are often marked by inclusions, segregations and pegmatitic injections. The best locations for quarries are found usually in the central part of the larger masses.

In southern St Lawrence and northern Lewis counties occurs an extensive and practically unbroken area of the granite which is traversed for several miles by the Carthage & Adirondack Railroad. This is one of the more accessible exposures in the region and is described at some length in the following pages as the Fine-Pitcairn granite. Smaller outcrops are so numerous that there is little object in giving them individual mention. The section about Gouverneur and eastward of there toward Edwards contains many isolated knobs, and the schistose rocks in that vicinity are seamed and injected by granite in a way suggestive of the existence of a great underlying body of that rock. At Natural Dam, just west of Gouverneur, a quarry has been recently opened in a small bosslike intrusion for the supply of road metal. The rock is a massive hornblende-biotite granite, but too variable in composition and texture to be workable for architectural purposes.

The syenite intrusions are of the usual Adirondack type, characterized mineralogically by the preponderance of feldspar which is normally of greenish to grayish green color, coarsely crystallized, and mainly the intergrowth of orthoclase and albite called microperthite. The feldspar constitutes up to 90 per cent of the entire mass. The dark minerals are pyroxene, hornblende and magnetite, of which the last named occurs rather abundantly for a rock of syenitic composition. Quartz is a very variable component. The prevailing dark color gives way to light shades of gray when the syenite has undergone granulation and recrystallization, and in some places to red which lends a certain similarity of appearance to the gneissoid granites. In such crushed phases there are always unreduced remnants of feldspar scattered through the fine groundmass, as evidence of their derivation from an originally coarse-grained rock.

The principal area of the syenite, thus far noted, lies on the western border of the Fine-Pitcairn granite bathylith, and has been described in some detail by C. H. Smyth, jr. There are smaller scattered areas in other parts of the western Adirondacks. The syenite is not well adapted for building stone on account of its prevailing dark color; moreover its tough unyielding nature in the mass offers difficulties in the way of extraction and cutting that would make the cost rather high. Its chief application seems to be for crushed stone, for which purpose it is superior to the granite and compares very favorably with the best trap. As a monumental stone it does not appear to show nearly the density and fineness of grain that are found in the syenites of Clinton and Essex counties.

Gabbro is not very common in this section and the occurrences, in part at least, seem to represent a basic, pyroxenic variety of the syenite. The few areas that have been noted up to the present time are in remote sections. They require little consideration, therefore, from an economic standpoint, though they may prove of some value as sources of material for local highway construction.

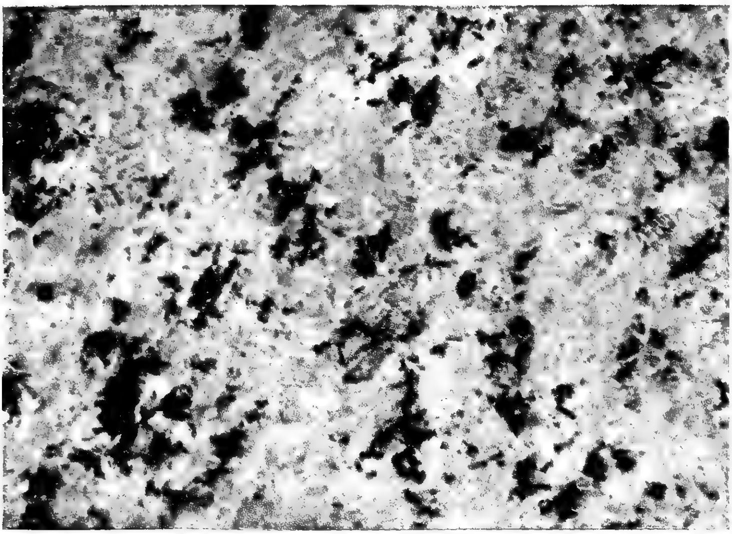
Trap dikes are likewise of minor importance, the recorded occurrences being few in number and of small size.

THE FINE-PITCAIRN GRANITE AREA

In the towns of Fine and Pitcairn, southern St Lawrence county, is an area of massive granite which, though not delimited as yet or shown on any of the published geological maps, must rank with the large granite exposures in the Adirondacks. By reason of its situation and adaptability to economic development this granite seems worthy of more than passing mention. So far apparently it has not been used for any purpose and its existence came to the writer's knowledge only through visits made several years since to the magnetic iron ore localities in its vicinity. The occurrence was revisited in the summer of 1911 when the section along the Carthage & Adirondack Railroad was examined with some care and samples taken for further study.

In places the granite possesses qualities as to physical structure, composition and appearance that seem to fulfil the requirements of a good architectural stone which could be employed very generally

Plate 10



Pink granite. Pine Island, Orange county

Red granite. Grindstone, St. Lawrence river

for foundation and construction work. Some variations, notably the coarse pink and white porphyritic phase, might find use for monumental stone. The convenient situation in regard to railroad facilities is an advantage not possessed by most of the localities where granite of similar character is exposed in the Adirondacks.

The section as measured along the winding route of the railroad extends about 8 miles in a general east and west direction. The first exposure on the west is near railroad milestone 56, which refers to Sacketts Harbor as the initial point, and the eastern border where the granite gives way to a well-foliated gneiss may be taken approximately at milestone 64, but is not sharply defined. The distance from Carthage, an important railroad center, is 25 miles, and from Watertown 40 miles.

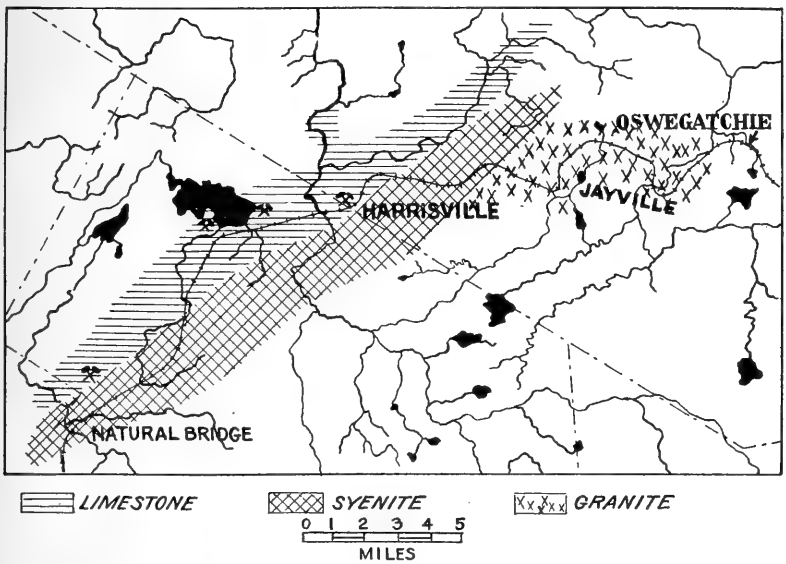
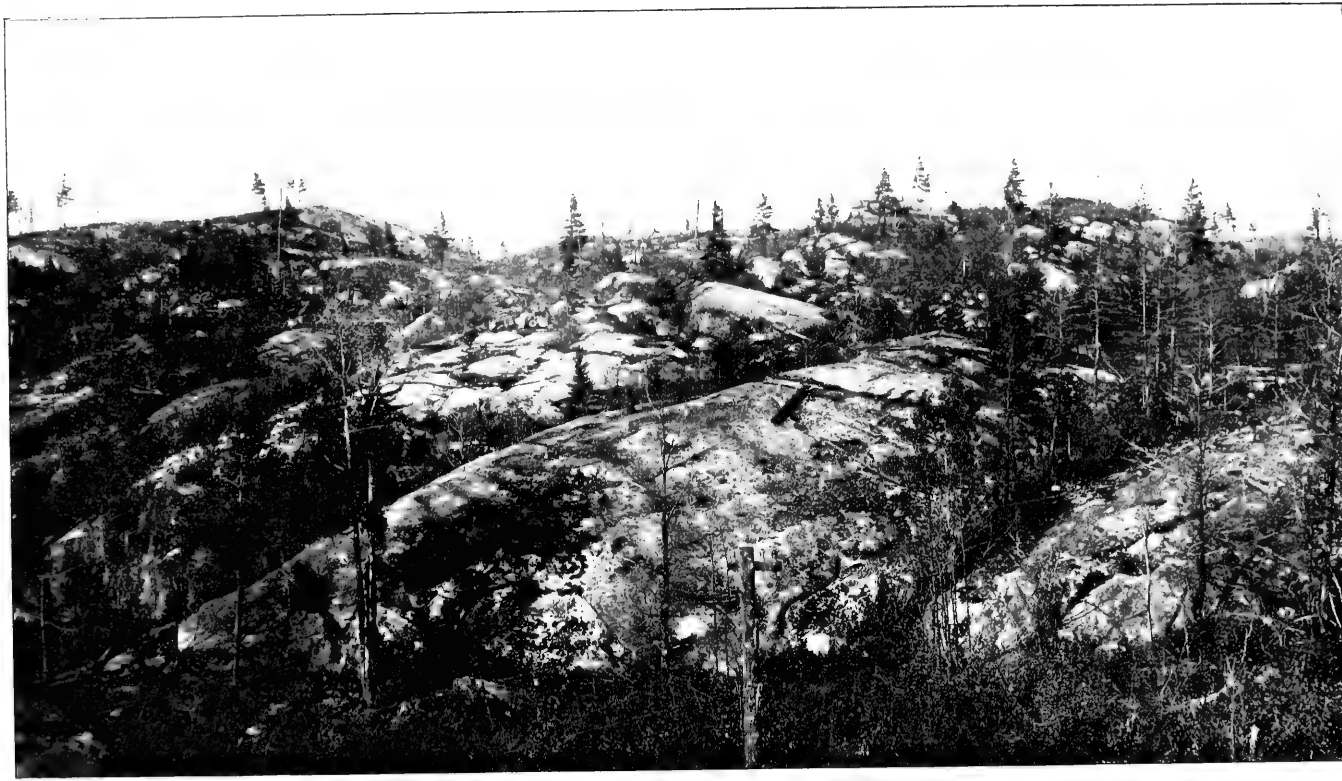


Fig. 7. Sketch map of the section along the Carthage and Adirondack Railroad from Natural Bridge to Oswegatchie

The exposures occur on both sides of the railroad in a series of ridges and hills that lend a rugged aspect to the topography though they seldom rise over 200 or 300 feet above the valley bottoms. They have no definite structural trend, in contrast with the regular north-east-south-west alignment of the ridges and valleys underlain by the older gneisses. The hills are more or less rounded, often hummocky on the summits, but there is little evidence of profound glacial erosion. The ice apparently has performed most of its work in removing whatever weathered and disintegrated material may have accumulated on the surface in the long interval between its advent and the exposure of the granite to atmospheric agencies. Since the Glacial period the rock has hardly been affected by weathering; fresh unstained samples may be secured from the natural ledges. Over much of the area the hill slopes have been denuded of their former soil and drift covering, as the result of recent forest fires exposing the surface to rapid erosion, so that the granite nearly everywhere is well exposed.

On the western boundary the granite is in direct contact with the great syenite intrusion of the Diana-Pitcairn area that has been mapped and described by C. H. Smyth, jr. The contact where crossed by the railroad lies just west of milestone 56. The syenite here has a very basic composition, containing much magnetite and dark silicates, with a coarse texture. It is much like gabbro in appearance. The contact of the two intrusives is not clean-cut, sharply dividing one from the other, but over a considerable distance both granite and syenite occur in alternating seams and patches or as interlaced bands. In the hasty examination of this mixed zone nothing definite could be learned as to the time relations of the two intrusions. The granite, however, is in general the most massive. The stretch from contact to about milestone 57 on the western border consists of gneissoid granite with a marked parallelism in the arrangement of the light and dark minerals and rather finely granular texture. The ledges between milestones 57 and 60 reveal the granite in thoroughly massive or indistinctly gneissoid condition and rather coarse in grain. The color is red, pink or sometimes mottled by the appearance of white feldspar in addition to the colored variety. One phase seen near milestone 59 shows porphyritic red feldspar in white groundmass of feldspar and quartz, specked with black hornblende crystals. At Jayville, a former iron-mining locality, situated near the middle of the area, there appears a considerable body of black hornblende gneiss which seems to have been caught up by the granite on its way to the surface and is possibly a part of the older Grenville series. It is in this gneiss that the magnetite bodies are found. The next ledge beyond Jayville consists of the normal red granite which continues to milestone 61 where a white granular gneiss with rusty streaks outcrops for a short distance. These are the only large inclusions

Plate 11



Glaciated hummocks of red granite on line of Carthage and Adirondack Railroad, near Oswegatchie

noted within the section traversed. On the eastern border between milestones 62 and 64 the granite becomes finer in texture, evidently the result of granulation superinduced by pressure metamorphism, but maintains its normal composition and for the most part its massive habit.

With the exception of the two large bodies of gneiss that probably represent included masses of the older Grenville rocks, the area where traversed is quite bare of inclusions or contrasting material of all kinds. The most common variations are produced by segregated stringers of quartz and pegmatite, but these have a very limited development. In general, the granite shows much uniformity, the changes of texture or appearance taking place very gradually.

The ledges are intersected usually by widely spaced joints, of which the vertical ones are in two series crossing at high angles so as to produce heavy blocks. Dimension stone of any commercial size could be obtained in most of the ledges.

The extent of the outcrop along the railroad, the only part where a complete traverse has been made, indicates that the granite covers a very large area. It extends no doubt for considerable distances to the north and south. Exposures of red, somewhat gneissoid granite of similar character have been noted by the writer in the northern part of Fine township and in the Cranberry lake region. Smyth mentions the occurrence of red hornblende gneiss in northern Lewis county which he states shows massive phases at many places and resembles as a whole a slightly modified hornblende granite. This may represent the southern continuation of the area under consideration; at any rate it may belong to a common magmatic source.

Microscopic examination. A study of thin sections from samples taken at different places within the area shows the rock to belong to the hornblende-biotite granites, with the two dark minerals in about equal proportions or with the hornblende predominant. They are, however, of subordinate importance to the feldspars and quartz, and in composition the stone ranks with the acid class in which the silica amounts to 70 per cent or more, as is confirmed by the results of chemical analyses. The feldspar ingredients include microperthite and microcline which lend the reddish color to the mass and a variable but minor quantity of plagioclase, mostly oligoclase. Quartz is plentiful. In the more massive types of the granite it occurs in rather large individuals having one or more crystal boundaries and to some extent as an intergrowth with the feldspar. Magnetite represents the principal iron ore, and no pyrite could be found in the sections. Apatite and zircon are among the accessory minerals.

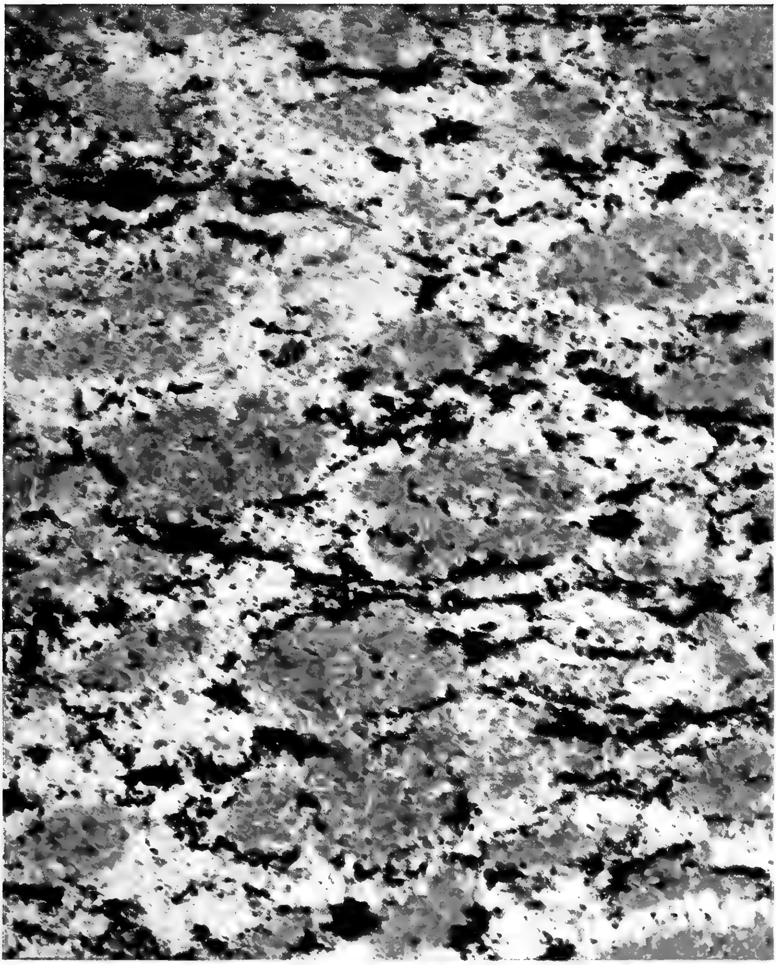
The sample taken from the surface reveals little weathering or decomposition that is detrimental to the appearance and strength of the stone. There is no sap or iron stain in any amount and the effects of exposure to the elements are mainly noticeable in the clouded appearance of the feldspars and the conversion of a part of the ferromagnesian silicates into chlorite.

In regard to texture the granite shows considerable variation from place to place, though within narrower limits it maintains a degree of uniformity that makes possible the production of an even grade of material. The coarse phase is thoroughly massive, sometimes faintly gneissoid, and has a semiporphyritic appearance, with feldspars measuring from .5 to 1 inch diameter in a fine groundmass of feldspar, quartz, hornblende and mica. Another variety has an even granular texture, ranging from medium to coarse. Still other types show quite marked gneissoid and cataclastic textures as the result of pressure metamorphism, more apparent on the edges of the area.

Chemical analyses. The chemical composition of the granite is fairly exhibited in the following analyses made from the samples taken at different places along the line of the Carthage & Adirondack Railroad. They reveal the essential ingredients in their respective proportions, but do not give the less important ones like manganese, zirconium and phosphorus which have little or no influence upon the general character of the granite. The summary consequently falls somewhat short in each case of the full amount. The analyses were made by R. W. Jones, of the Museum staff.

	No. 1	No. 2	No. 3
SiO_2	75.01	72.69	70.03
Al_2O_3	12.88	14.11	13.12
Fe_2O_3	.02	.26	2.04
FeO	2.01	2.89	3.66
MgO	.41	.28	.74
CaO	1.10	.64	1.61
Na_2O	3.67	2.37	2.21
K_2O	4.16	5.16	4.14
H_2O+	.32	.24	.53
H_2O-	.08	.02	.06
	99.66	98.66	98.14

Plate 12



Porphyritic granite. Jayville, St Lawrence county

Sulphur was tested for, but not found. Analysis 1 represents the coarse massive granite from milestone 59. Analysis 2 is based on the finer grained massive rock from milestone 62. No. 3 relates to a sample taken from near the eastern edge of the area at milestone 64, which shows a strong cataclastic texture.

Physical tests. The following tests of the coarse and fine sorts of the granite from Jayville were made in the laboratories of the State Museum. The samples were taken from the natural outcrop.

Specific gravity	2.70	2.63
Weight, pounds a cubic foot	168.5	164.1
Ratio of absorption, per cent	.31	.264
Pore space	.99	.69

THE DIANA-PITCAIRN SYENITE

The syenite intrusion, previously mentioned as forming the western boundary of the red granite in southern St Lawrence county, needs only brief description in this place. It can not be considered to offer opportunity for the extraction of building materials on a large scale, though the massive phases of the rock are well adapted for highway and concrete material. The somber color which is generally characteristic of this rock in the Adirondack exposures is unsuited to most architectural purposes.

The syenite area is well shown on the large geological map of the State. Its boundaries were traced by C. H. Smyth, jr, who has also given a detailed account of its geological and petrographical features in his paper on "Crystalline Rocks of the Western Adirondack Region."[1] The intrusion extends in a northeast, southwest direction across the townships of Diana, Lewis county, and Pitcairn, St Lawrence county, for a distance in all of 20 miles. Its width is usually less than 5 miles and its area may be estimated at not less than 75 square miles. The Carthage & Adirondack Railroad, after passing out of the red granite near milestone 56, crosses the northern part of the syenite intrusion and enters the limestone belt on the west just beyond Harrisville. The railroad again follows the syenite for some distance in the stretch from Bonaparte lake to Natural Bridge, near the southern end of the intrusion.

The syenite is grayish green to dark green, heavy and very tough rock composed largely of feldspar but containing considerable

[1] N. Y. State Museum Report 51, v. 2, 1899.

amounts of the ferromagnesian minerals and magnetite. The coarser, massive phase, which may be regarded as the original type, is only occasionally observed in the field, for the whole mass seems to have undergone more or less granulation and recrystallization from pressure metamorphism. This circumstance indicates an earlier period of intrusion for the syenite as compared with the red granite of the same region, though the contact relations where observed did not afford any definite evidence in that particular.

Microscopic examination. The feldspar is principally a microperthitic intergrowth of orthoclase and albite, with a little acid plagioclase. In many places the feldspar constitutes over 80 per cent of the entire rock. A deep green pyroxene is usually observable in small, irregularly bounded individuals with which a darker hornblende is often associated in a manner suggestive of its derivation from the pyroxene. Quartz and magnetite are important accessory minerals, the former being particularly abundant in the more foliated varieties. Zircon and titanite also occur and the presence of a little pyrite may usually be observed.

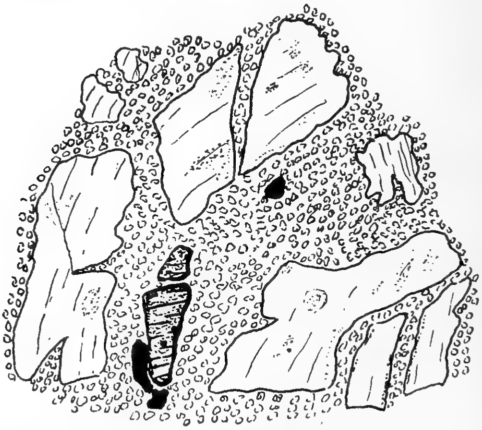


Fig. 8. Microscopic appearance of syenite from near Harrisville. Shows groundmass of crushed feldspar, with larger fragments of the original crystals, also a little pyroxene and magnetite

The syenite often has a porphyritic appearance as the result of crushing which has reduced all but a small remnant of feldspar to a fine, granular aggregate. The texture is seldom perfectly massive.

Chemical analysis. The chemical character of the syenite is illustrated by the following analyses. No. 1 is of a sample taken from the eastern contact near milestone 56 on the Carthage &

Adirondack Railroad (R. W. Jones. analyst). No. 2 is quoted from Smyth's paper:

	No. 1	No. 2
SiO_2	63.11	65.65
Al_2O_3	18.02	16.84
Fe_2O_3	2.12	.....
FeO	3.53	4.01
MgO	1.43	.13
CaO	2.56	2.47
Na_2O	4.08	5.27
K_2O	4.26	5.04
H_2O+	.26	.30
$H_2O?$	.09	
	99.46	99.71

Sulphur is not shown, though present in small amount.

Physical tests. A sample of the syenite from milestone 55 Carthage & Adirondack Railroad, was tested in the laboratories of the State Department of Highways: Specific gravity, 2.705; weight, pounds a cubic foot, 169; absorption, pounds a cubic foot, .07; hardness, 18.1, toughness, 15. Tests by the writer showed ratio of absorption .148 per cent, pore space .402 per cent.

PARISHVILLE RED GRANITE

A monumental and structural granite has been quarried at Parishville in eastern St Lawrence county. It has a dark red fine-grained body in which appear curved and branching veinlets of bright red colors and somewhat coarser grain, but of the same mineral compositions as the rest. The veining is not sharply defined but shades off on the borders and in places develops into round or irregular nuclear patches which give the effect of clouds of lighter color. The appearance of polished surfaces is attractive as it is quite rare among stones of this class. The variation in grain is not the result of pegmatitic injection, but of different conditions of crystallization during a period of resoftening of the rock. The granite belongs to the Adirondacks granite gneisses and is composed of feldspar, biotite and quartz, the last in rather small amount, with some hornblende, magnetite and zircon and a little chlorite.

Crushing tests on the granite made at the Clarkson School of Technology at Potsdam showed an ultimate resistance of 20,000 pounds to the square inch. The chemical composition, as determined by L. K. Russell is as follows:

SiO_2	66.78
Al_2O_3	13.01
Fe_2O_3	6.50
MgO	.92
CaO	1.31
Na_2O, K_2O	10.89
H_2O	.51
Total	99.92

The quarry is owned by the St Regis Red Veined Granite Co., and the output thus far has been mainly monumental stock.

GRANITIC ROCKS IN THE EASTERN ADIRONDACKS

The eastern Adirondack region, or so much of the highland as is included in the Lake Champlain drainage area convenient to rail and water transportation, is made up largely of igneous rocks belonging to the class of anorthosite, gabbro, syenite and granite. Their intrusion took place in Precambric time before the final stages of uplift and metamorphism that profoundly modified the region during that period had been accomplished. Laminated gneissoid characters are very common; in fact there are comparatively few localities where the igneous rocks show unchanged, massive structure. The existence of unreduced or slightly modified residuals affords a basis for quarry operations in connection with building and monumental stone of the best quality, while there is an unlimited supply of material suited to many purposes for which absolute uniformity of texture or an attractive appearance is not essential.

Rocks of the anorthosite class are most widespread in this section of the Adirondacks. They have a very simple mineral composition, consisting almost wholly of basic plagioclase feldspar, usually labradorite and in their unaltered phase are characterized by very dark colors. The anorthosites spread over most of Essex county as a single, practically unbroken, area that embraces all the more prominent Adirondack peaks within its borders. They extend in force westward into Franklin county, but have little representation in Clinton county, the southern border of which is nearly coincident with the northern limits of the main area. An outlying intrusion of small compass occurs, however, in Beekmantown and Altona townships of Clinton county about 20 miles north of the county line.

Plate 13

The Moore syenite quarry, Ausable Forks

In their typical development the anorthosites are too coarse in texture and too dark in color to find favor as building materials. Much of the interior part of the area is made up of this very coarse type. Along the borders they are usually finely textured owing to secondary crushing, and their color then becomes lighter if not influenced by an abnormal proportion of iron-bearing minerals. Some variations of this border phase present a uniform, even granular appearance, closely resembling in mass a true granite with which the anorthosite compares favorably as regards durability and strength.

Few quarries have been opened in the anorthosite and these are situated in the northeastern part which is most accessible to the lake. Old quarry sites exist on Splitrock mountain between Westport and Essex village and near Keeseville. Some work has been done, also, on the small outlier in Beekmantown and Altona townships, Clinton county. More recently attention has been given to the locality near Ausable Forks, where there is an area underlain by uniform light-colored anorthosite.

The syenites and granites of this section are found in smaller intrusions in the midst of gneisses which surround the anorthosite. Both classes show a tendency toward laminated structures and on that account have limited quarry possibilities. The syenite is dark green, while the granite is mostly a red variety. A local development of massive syenite that occurs at Ausable Forks on the border of the anorthosite, has recently come into prominence as a source of monumental stone. The red granite has been quarried only to a small extent.

The gabbros have little importance economically except as possible sources of supply of road metal for which the massive types would appear to be excellently adapted by reason of their usually tough, firm nature. They form small intrusive knobs in the gneisses and also are found quite commonly in the anorthosite area.

In this connection mention may be made of the diabase dikes which occur all over the region, and are particularly abundant in southern Clinton county. Like the other igneous rocks that have been mentioned they are of Precambric age, though they show no effects of pressure metamorphism and must have been intruded in very late Precambric time. They seldom attain a workable size, the average thickness being not more than 10 or 15 feet. For road-making they offer the best material to be had anywhere, but so far no very accessible dikes of large size have been found.

AUSABLE FORKS SYENITE AREA

The vicinity of Ausable Forks, about 15 miles west of Lake Champlain and 24 miles by rail southwest of Plattsburg, presents many advantages for quarry operations in connection with both anorthosite and syenite. For several years past a considerable quantity of monumental stone has been shipped from this section and recently additional developments with a view to the extraction of building stone in a large way, as well as monumental stock, have been planned.

The main anorthosite intrusion of the central Adirondacks extends from the south to within a short distance of the confluence of the east and west branches of the Ausable river, where the village is

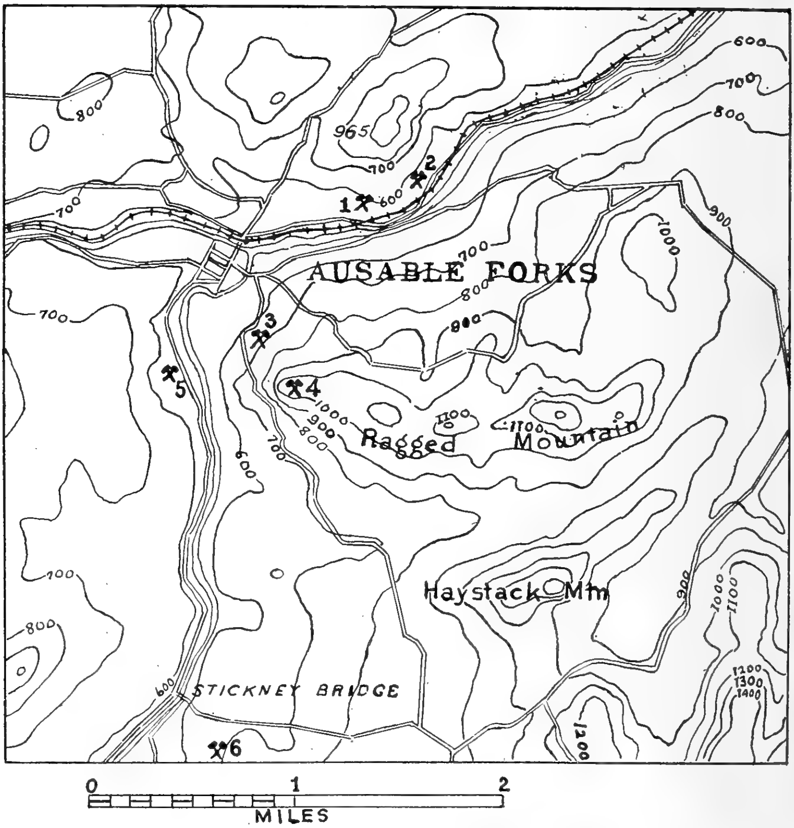


Fig. 9 Map of the quarry section about Ausable Forks. 1–5 are quarries in green syenite; 6 is anorthosite quarry

Plate 14

Part of the Moore syenite quarry, Ausable Forks

situated. The rock outcrops in a series of low hills and ridges which are mostly bare of soil and afford natural quarry sites. It is of medium to light gray color as seen in exposures, or in rough dressed surfaces, about the equivalent of a gray granite, for which it serves well as a general building material. The anorthosite belongs, of course, to the border phase of the intrusion, characterized by a granulated feldspar ground mass with rather more than the usual percentage of dark silicates.

The syenite which is quarried principally for monumental purposes occupies an area between the anorthosite on the south and the red gneisses that extend over most of the county immediately north of the Ausable river. It outcrops in the first ridges just north of the village, and also on the west side of Ragged mountain on the south bank and in the triangle formed by the two forks of the Ausable. The different exposures belong very likely to a single boss of the syenite which has forced itself up along the gneiss-anorthosite contact. The rock is of medium grain, massive. In color it varies from dark to very dark green as seen on rock face and polished surfaces, but grayish green on hammered work. Its perfect polishing qualities and ability to take the finest tracing which it shows in strong relief, combine to make it one of the most attractive monumental stones on the market.

The Moore quarry

The syenite quarries are located on both sides of the river. Those on the north side are situated along the ridge that lies a little distance from the town and north of the railroad. The Moore quarry is near the base of the ridge which rises steeply at first so as to afford a good working face of 100 feet or more, and then more gradually to the summit which is over 400 feet above the railroad. There is practically no soil covering on the rock and weathering has produced no more than a slightly bleached layer, which at a few inches depth passes into the normal rock. No sap or stain is apparent. The rock is broken into large blocks by two vertical joint courses running N. 40° E. and N. 50° W. An inclined course cuts across these in a direction N. 20° W. and dips 45° northeast, in conformity with the surface slope, giving the effect of a sheeted structure. The rock is said to split easiest in a direction parallel to the inclined joint systems. Several trap dikes from 10 inches to 2 feet thick intersect the ledge in a northeast-southwest direction. They have exerted little contact effect upon the syenite and in some respects are an advantage to the quarry work, as they form a natural back from which the rock may be broken away.

The syenite is medium to fine in texture, the feldspar which composes the greater part of the mass ranging from 5 mm down to 2 mm in diameter. The color in the quarry is bright green to yellowish green, and of polished surfaces a lustrous dark green that appears nearly black when seen from a distance. The stone from this quarry is sold under the name of "Adirondack green granite."

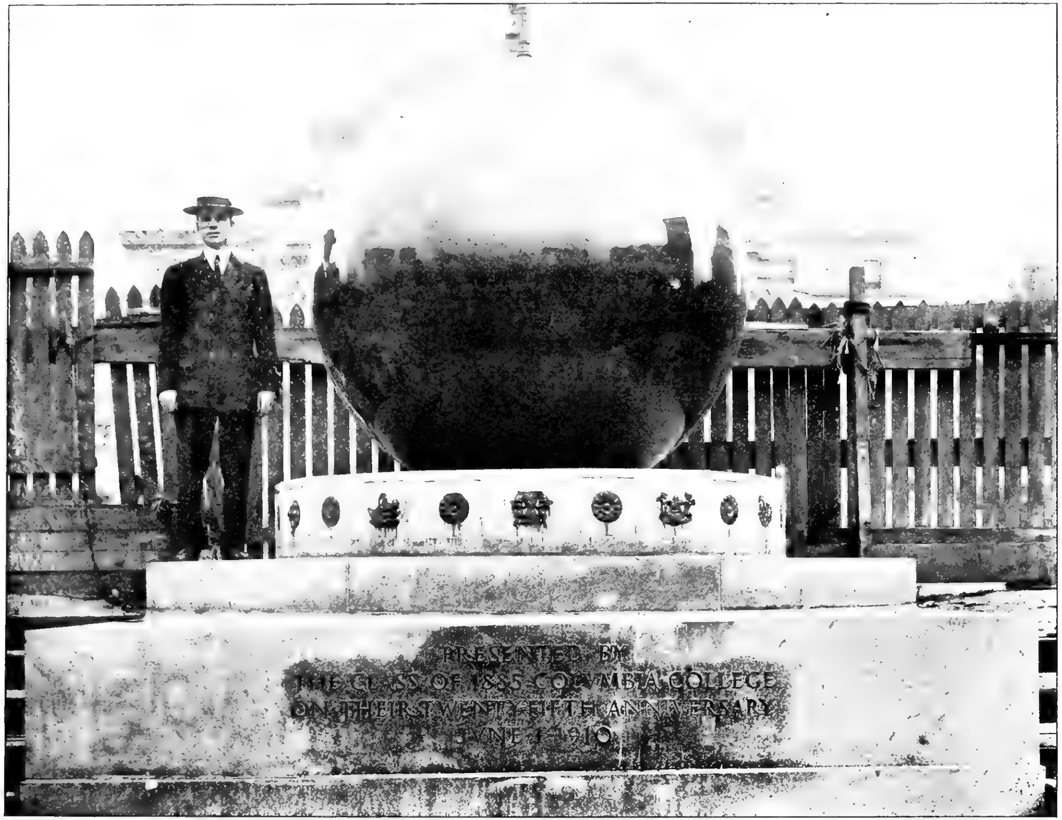
The quarry was first opened by Moore Brothers of Barre, Vt. It was later taken over by the Adirondack Granite Co., a consolidation of several quarry properties in the vicinity of Ausable Forks. Recently it has been worked under lease by J. H. Moore.

Microscopic examination. The composition of the syenite is about 75 per cent of feldspar and 25 per cent of other ingredients, including pyroxene, quartz, magnetite and zircon. The feldspar consists of microcline, microperthite and oligoclase, all in stout prisms with interlocking borders. The microperthite is very abundant and affords beautiful examples of this peculiar intergrowth, the alternating bands of microcline and albite being unusually large. The pyroxene has an emerald green color and is strongly pleochroic. Zircon is quite abundant. There is very little evidence of alteration among the minerals, but some secondary limonite has been deposited along the sutures and pores, probably filtering in from the surface. The feldspar and quartz are crossed by microscopic fractures in the direction of the grain similar to those found in granites, but smaller in dimensions and less abundant. No sulphides were observed in the sections.

Physical tests. The syenite from this quarry has a specific gravity of 2.71, or a weight of 169 pounds to the cubic foot. The crushing strength is 14,734 pounds a square inch. The ratio of absorption is .155 per cent or .26 pounds to the cubic foot.

Ausable Granite Company's quarry

The first syenite in the Ausable Forks area was quarried from the ridge a little east of the Moore quarry by the Ausable Granite Company, later consolidated with the Adirondack company. The quarry has not been operated for the last few years, as the other localities offer better advantages for extracting stone of uniform grade. The general character of the rock, however, is very similar to the material in the Moore quarry. The quarry supplied both monumental and building stock in limited quantity.



Polished sphere of green syenite, quarried by the Adirondack Granite Company at Ausable Forks. The sphere is 7 feet in diameter and weighs approximately 16 tons, the original block from the quarry having weighed 39 tons.

The Charles Clements quarry

The Charles Clements quarry is situated south of the Ausable on the shoulder of Ragged mountain, overlooking the village of Ausable Forks. It yields a fine-grained syenite of darker color than that from north of the river, though it is no doubt a part of the same intrusion. The quarry is opened as a pit and thus is worked to some disadvantage, though the depth is not sufficient as yet to complicate the operations. The quarry belongs to Charles Clements, a dealer in monumental stone, of Boston, who has shipped the product in the rough.

Microscopically, the syenite in the area south of the river differs considerably from the type described under the Moore quarry. The syenite here is evidently a border phase of the intrusive mass, characterized by fine grain, and a larger percentage of the dark constituents, with reaction minerals like garnet. Owing to its fine texture, it splits with a smooth or conchoidal fracture like a trap. Along with the increase of the ferromagnesian minerals there is a gain also in lime-soda feldspar which shares importance with the alkali varieties. It is a basic phase of the syenite which in other places in the Adirondacks may be observed to grade over into a gabbro.

The texture of the rock is even-grained, massive, showing no trace of the gneissoid arrangement that often accompanies the basic gradations. The jointing is at wide intervals and almost any size of block can be quarried. There is no well-developed sheet structure, but a series of unequally spaced bed joints is present.

The Carnes quarries

The Carnes quarries, owned by F. G. Carnes of West Chazy, are situated about one-half of a mile south of Ausable Forks on the western continuation of the Ragged mountain exposure. They are not as yet developed for supplying large quantities of stock, but have been opened sufficiently to prove that there is material of good quality. One quarry, called the Keystone, lies at the base of the mountain, between the highway and the river. It yields a green syenite of lighter shade than that from higher up the mountain. The quarry lands in this location cover 35 acres.

On the opposite side of the East branch the syenite appears again along the slopes of a low ridge that is partly covered with terraced sand deposits. The Emerald quarry is situated in this exposure. The ledge affords a face from 15 to 25 feet high and about 400 feet long. There is in all 300 acres in the property. The syenite is intersected by widely spaced block joints. It is a dark green rock of fine texture. It takes an excellent polish and is well suited for monumental stone.

Under the microscope the syenite from the latter quarry presents some peculiarities not noted in the other occurrences. The chief feature is connected with the ferromagnesian minerals which consist mainly of a dark hornblende in the place of the usual green diopside, and a smaller proportion of an orthorhombic pyroxene that corresponds to hypersthene. Quartz is more abundant than usual for syenite, occurring in small grains on the borders and in the interior of the feldspars. The latter comprise microperthite, microcline and oligoclase. The accessory constituents include magnetite, zircon, apatite and titanite. The secondary products of alteration are mostly chlorite, which is observed on the borders of the hornblende, and limonite. The texture is even-granular massive.

AUSABLE FORKS ANORTHOSITE AREA

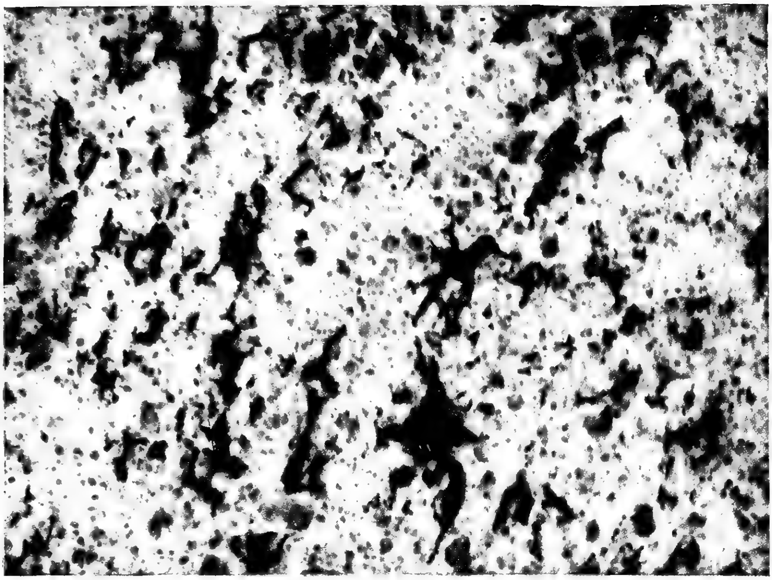
In the last few years some attention has been given to the quarrying of anorthosite for building and monumental stone in the vicinity of Ausable Forks. The anorthosite outcrops on the road from Ausable Forks to Jay, beginning just south of the Stickney bridge along the ridges that limit the valley on either side.

The anorthosite belongs to the granulated type in which the originally coarse feldspar crystals are only now and then evidenced by unmashed individuals which in their surroundings of fine-grained material appear like the phenocrysts in a porphyry. The color is gray of light or medium tone while the uncrushed feldspars have a dark greenish or bluish appearance and an iridescent play of color. Some types contain much pyroxene, which is black in the hand specimen; the stone then is similar in appearance to a medium-grained or coarse-grained granite.

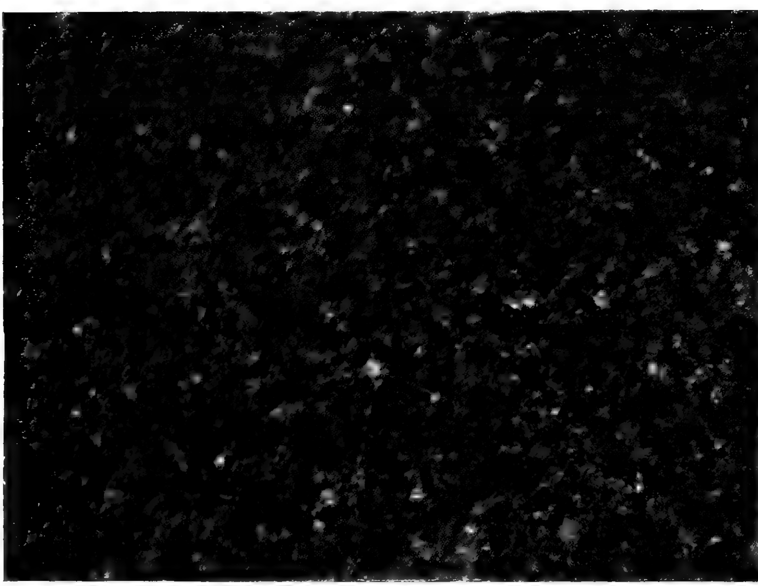
Most of the stone has been shipped from a quarry situated one-half of a mile southeast of the Stickney bridge, formerly worked by the Adirondack Granite Co. It is a small opening with a face about 20 feet high, but the ledge extends fully 500 feet with a face 50 feet high. The stone from this quarry was used in the two first stories of the Locomotive Engineers Building in Cleveland, Ohio, and in the Adirondack National Bank Building at Saranac Lake.

The rock is traversed at rather wide intervals by two sets of vertical joints running N. 50° W. and N. 35° E. respectively. There is a less marked division in a plane inclined about 30° from the

Plate 16



Gray granite (Anorthosite). Ausable Forks



Green syenite. Ausable Forks

horizontal. It possesses a marked rift and grain structure which follows the direction of the vertical joint systems and which has already been described in the earlier discussion of that structure. Blocks of any merchantable size can be quarried: one containing about 6000 cubic feet was exposed in the course of operations in 1911.

The same character of rock extends eastward from this opening on to the Loren Williams place, between the North Jay and Stickney Bridge roads, where there is a very extensive exposure and the outcrop is found on the sides and top of the knob next south of the quarry opening, but the rock here has a coarser texture with a larger proportion of uncrushed feldspar.

Microscopic examination. Thin sections of the anorthosite examined under the microscope reveal its simple mineral character. It is mainly feldspar of one kind, a basic plagioclase corresponding to labradorite in optical properties. The individuals have been broken down to small grains 2 or 3 mm in diameter, which are interlocked, however, as thoroughly as the components of any granite. Effects of compression are also evidenced by strain shadows in the larger residual crystals. The feldspar shows some alteration to mica around the borders, but otherwise is fresh. The dark constituents are hornblende and pyroxene, frequently intergrown and showing irregular boundaries. There is a little magnetite or ilmenite in fine particles, but no pyrite.

Physical tests. The results of physical tests indicate that the anorthosite meets all practical requirements for a building stone. The crushing strength measured on a tube tooled down but not polished was 14,735 pounds a square inch, or equal to that of an average granite. The specific gravity is 2.75, or a little heavier than granite, corresponding to a weight of 172 pounds to the cubic foot. The absorption is low, with a ratio of .127 per cent. The hardness, according to the tests of the bureau of research, State Department of Highways, is 17.6 and the toughness 6. Another sample of anorthosite from Ausable Forks, locality unspecified, showed the following results: specific gravity 2.74; abrasion (French coefficient) 10.5; hardness 18.7; toughness 10.

Red granite, Ausable Forks

An outcrop of granite on the Clintonville road 2 miles east of Ausable Forks has afforded a limited quantity of monumental stone of which some has been used locally and the rest shipped to dealers. The rock is an interesting type, as it belongs to the true granites, being composed of feldspar and quartz in normal proportions, but on the other hand contains no dark silicates of the mica, amphibole or pyroxene families. In the place of such minerals, however, it carries a large amount of magnetite which ordinarily is a very minor constituent of granite. This mineral constitutes about 15 per cent of the entire rock, its relative abundance more than compensating for the absence of iron-magnesia silicates in effect upon the specific gravity. The latter is 2.8 which corresponds to a weight of 175 pounds to the cubic foot, which is very high for granite. The color is purplish brown to dark red. The grain is regular and fine, the average diameter of the quartz and feldspar grains being under 2 mm. The appearance of the polished surfaces is attractive.

The quarry is a small opening with a face of about 12 feet. It is on property owned by Mrs Beane of Ausable Forks.

THE KEESEVILLE ANORTHOSITE AREA

The anorthosite exposures in the vicinity of Keeseville near Lake Champlain, have been the source of fairly large quantities of building and monumental material. The rock is mostly the light, granulated variety that characterizes the peripheral zone of the great Adirondack mass. The stone has been sold under the name of Ausable granite.

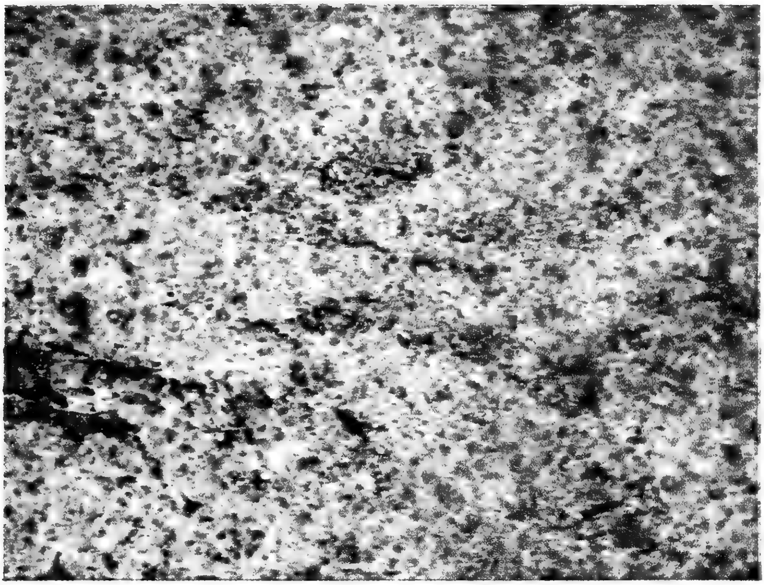
Prospect Hill quarries

The Prospect Hill quarries are situated on the northern and western slopes of that prominence, a rounded knob 300 feet or more high, lying just south of Keeseville. The northerly quarries once belonged to the Ausable Granite Co., and are mentioned by Smock as in active operation at the time of his investigation in the period 1880–90. The company also operated a dressing and monumental works at Keeseville.

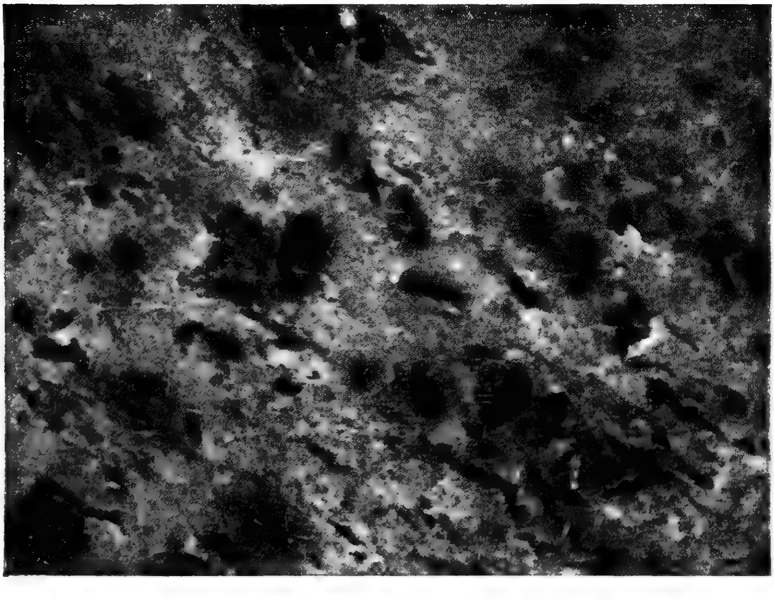
The stone of these quarries is medium to coarse in texture, depending on the relative proportion of the granulated and residual uncrushed feldspar, and has a gray color. The rock surfaces show glacial striations and polishing, but are almost unaffected by weathering influences.

Smock describes two quarries as operative, a lower one to the north producing a coarse variety, and an upper quarry about 20 rods south of the former and higher up the hill, each equipped with a single derrick. The quarrying of dimension stone must have been

Plate 17



Gray granite (Anorthosite). Keeseville



Green granite (Anorthosite). Keeseville

expensive, as the jointing is irregular in regard to direction and spacing. The principal uses of the stone appear to have been in monumental and decorative work. It was employed in the trimmings of the Y. M. C. A. building in Burlington, and also in the interior decoration of a Philadelphia church, but had the widest sale for monuments, of which there are many specimens in the cemeteries of that vicinity. A local example of its use in buildings is found in the French Catholic church at Keeseville, which, however, was constructed mainly of the quarry waste. At the time the quarries were worked, the branch railroad from Port Kent to Keeseville had not been built and all the stone had to be hauled to the lakeside by teams.

G. P. Merrill in his "Stones for Building and Decoration" speaks of the Keeseville stone as "admirably adapted for polished columns, pilasters, and other decorative work." But he also remarks that the material in some places shows minute fractures which may prove detrimental to its weathering qualities.

Physical tests. The stone is credited by Smock with a crushing strength of 29,000 pounds to the square inch, which is higher than the average. The specific gravity is around 2.75, indicating a weight of 175 pounds to the cubic foot. Ratio of absorption, .066 per cent.

Empire State Granite Company's quarries

The Empire State Granite Co. has been engaged recently in the development of quarry lands to the west of Keeseville, near the Clintonville road, on property owned by George W. Smith of Keeseville. The company has also an area on the west side of Augur lake which it has prospected to some extent.

The anorthosite in this section shows more uniformity of character than that on Prospect hill and its structural features are better adapted for quarry operations. It is traversed usually by two series of vertical joints crossing at right angles. A horizontal series is also present. It splits readily with plug and feathers in two directions which correspond to rift and grain in granite. Dimension stone and paving blocks can be quarried without more difficulty probably than with ordinary granites. The joints show very little sap and the stone is practically fresh from the surface.

Two openings have been made on the Smith property west of Keeseville. At the more westerly one the anorthosite forms a ridge with a nearly vertical rise on the north of about 50 feet. This is being developed as a side-hill quarry. The fractured surface of the rock has a light green color with occasional mottlings of dark green to black caused by uncrushed remnants of the feldspar. The polished surface appears sea-green with the same mottling, but showing also more or less the iridescence peculiar to labradorite. Close inspection reveals fine specks and threads made up of red garnet. A 12-foot diabase dike intersects the ledge in an east-west direction.

The second quarry, 1000 feet northeast from the former, is a pit which at the time of the writer's visits was about 20 feet deep. The stone is much coarser with more of the residual feldspar crystals distributed through the mass. The jointing is in two directions — northeast and northwest — with a horizontal series from 3 to 4 feet apart. Along two of the northeasterly joint seams have been intruded dikes of trap and syenite porphyry, the former 3 inches and the latter 18 inches wide.

The anorthosite is exposed on the west shores of Augur lake in a series of cliffs from 75 to 100 feet high. The sides of the cliffs have been exposed directly to the weather ever since the glacial period at least, yet the weathered stone is only a fraction of an inch thick. This seems to indicate good resisting powers to frost and agencies of decomposition. The jointing is very heavy, the intervals often being 8 or 10 feet. Some of the rock contains biotite in the place of the usual pyroxene.

Microscopic examination. The general run of the stone from the different localities may be described as composed of labradorite in large part, the average being from 75 to 85 per cent. On account of the frequent residual feldspar crystals, the grain would be called coarse, although the groundmass itself is fine grained. The larger feldspars are from 10 to 20 mm in diameter, with occasional individuals still larger. The principal dark mineral is diopside, which appears emerald green in thin sections. Hornblende and biotite are locally developed and take the place of the pyroxene. Garnet is nearly always present in aggregates of small grains arranged about the pyroxene, from which it has no doubt been derived in the metamorphic process. Ilmenite is in small amount and an occasional speck of pyrite can be seen. The decomposition products are kaolin from the feldspar and chlorite from the ferromagnesian minerals. They are not in sufficient amount to cause any noticeable weakening of the structure.

Physical tests. Specimens of the anorthosite were tested by the office of public roads, United States Department of Agriculture, at

Washington with the following results, no. 1 referring to the stone from the Smith property and no. 2 to that at Augur lake.

	No. 1	No. 2
Crushing strength, pounds a square inch	20,500	18,500
Specific gravity	2.75	2.70
Weight, pounds a cubic foot	172	168
Water absorbed, pounds a cubic foot	.51	.49
Wear (French coefficient)	11.7	10.4
Hardness	18	18
Toughness	13	10

The physical tests indicate that the material meets all the ordinary requirements of building material. There can be little doubt as to its durability under weathering conditions, though it has not been proved by actual service in buildings. For polished work it should also prove acceptable on account of its rare color. The only drawback to that use seems to be the presence in some of the polished specimens of minute hairlike fractures visible on close inspection. These are the more apparent by reason of the translucent background, but as evidenced by the crushing strength and absorption do not materially weaken the general structure.

Quarry of C. B. White, Augur lake

Along the west side of Augur lake anorthosite outcrops over a large area, forming a broad ridge which breaks off at the lakeside in a line of perpendicular cliffs 100 feet high. It is mostly a light-colored labradorite rock, of medium grain, in general appearance not unlike gray granite. It contains scattered crystals of pyroxene and occasionally some biotite. In places these minerals become sufficiently abundant to give a rather dark tone to the rock surface, but generally they are of subordinate importance. The minor accessory constituents are garnet, ilmenite and a little chlorite and kaolin from decomposition. The anorthosite is undoubtedly a good durable building stone.

The property owned by Mr White includes a quarry opening which lies on top of the ridge above the lake. The quarry was last worked in 1892; the product was employed in the construction of the Criminal Courts Building in New York City. A large quantity of rough stone, much of it suitable for dimension stone, was left in the quarry. The principal drawback to operations is the long haulage to the railroad, the nearest shipping point being Keeseville, the terminus of a short branch railroad that connects with the Delaware and Hudson line at Port Kent. The quarry is about 5 miles in a direct line from the shore of Lake Champlain.

THE SPLIT ROCK ANORTHOSITE AREA

The great anorthosite intrusion of the central Adirondacks has its most easterly exposure on Split Rock mountain, the bold ridge that forms the western shore of Lake Champlain for several miles, beginning just north of Westport. The whole mountain is practically made up of this rock and its gabbroic type, though on the north end it gives way in places to the Grenville series of limestones and schists which have been surrounded and borne up apparently by the igneous mass. The darker phase of the anorthosite is mainly in evidence in the exposures along the lake and on the north end. The bulk consists of the grayish feldspathic variety which has been more or less comminuted by regional compression. In some parts of the mountain the rock has a distinctly porphyritic appearance by reason of the large residual feldspar crystals, but again it shows a local development that is characterized by uniformity of grain.

The only quarry workings in this exposure that are known to the writer are on the eastern face of the mountain, about one-fourth of a mile back from the lake and at an elevation of from 500 to 600 feet. They are reached by a trail from the Westport road and also from the lake by following the old tramway line that was used to lower the stone. The locality is just north of the little bay called Barn Rock harbor on the United States geological sheet, but is mentioned as Barron Rock in Smock's report of 1888. According to the latter, the quarries were first opened in 1881 by the Champlain Granite and Marble Co., and reopened in 1887 by the Adirondack Granite Co. Under the latter company, as the writer has been informed, a quantity of building and monumental stone was shipped, some of the building material having been sent to New York City. By 1890 the quarries were again closed and have not been worked since.

General characters. The stone from the quarry site has a grayish body with porphyritic feldspar of somewhat darker color. It is practically all feldspar, belonging to the very basic plagioclase series. Small, scattered crystals of pyroxene (diopside), magnetite and quartz occur in the interstices of the feldspar aggregate. The magnetite shows slight decomposition to hematite, but there is little pyrite, judging from the samples that were examined.

DANNEMORA GRANITE AREA

A gneiss of massive granitic appearance, pink or gray in color, outcrops on the ridge north of Dannemora, Clinton county. The exposure is a part of the larger belt of granitic and syenitic gneisses which are developed extensively in the northern Adirondacks and are included in the Saranac formation of Cushing. In places the gneisses lose their usual foliated structure and when free of admixture with other contrasting gneisses are well suited for building and engineering materials. They contain a predominant proportion of the feldspar minerals, with moderate to small amounts of quartz and little of the dark silicates in the form of hornblende and diopside. Magnetite is a variable constituent, ranging up to 7 or 8 per cent in amount. The texture is fine and compact, the result of crushing and to some extent of recrystallization of coarse originals.

The principal quarries in this area are situated on the ridge back of the State Prison and Hospital grounds; they have been worked for the supply of building stone for these structures and to some extent for other purposes. They belong to the firm of Allen & Cunningham who have operated them under the name of the Dannemora Granite Co.

There are two openings situated less than a mile from Dannemora and from 300 to 400 feet above it. The more northerly one shows a pink gneiss of fine grain, containing magnetite as the principal dark ingredient, with more or less hornblende. There are occasional bunches of the dark minerals and also bands of pegmatite. The rock is jointed fairly regularly by two vertical veins running north-south and east-west respectively. Two trap dikes cut the granite just south of the quarry. The rock face is about 20 feet high. At the second opening the granite has a similar character and shows pegmatitic and dark-colored inclusions. A 4-foot trap dike intersects the quarry face in an east-west direction. The face is 100 feet long and 30 feet high. Jointing is prominent in two directions as at the first quarry. The streaks and inclusions are the main handicap to the working of the quarry for building purposes, although by selection a good quality of material can be obtained.

GRANITE IN THE TOWN OF WILTON, SARATOGA COUNTY

A massive gray granite is found in the town of Wilton, Saratoga county, about 2 miles north of Saratoga Springs. It outcrops on the easterly-facing ridge which marks the first elevations of the Precambric highland of the Adirondacks to the west of the Paleozoic plain. The area is of unknown extent but to the north the granite soon disappears, being succeeded by Grenville schists and quartzites with bands of crystalline limestone. The granite has a fine granular texture, the result probably of crushing of a much coarser rock under pressure metamorphism. There is evidence of the original coarse grain in occasional fragments of feldspar and quartz which have escaped the general reduction. In its appearance and physical characters it resembles the earlier series of Adirondack granites, but does not show their well-defined laminated structure owing to the small proportion of dark minerals.

The granite was quarried quite actively at one time, and the old quarry face is still conspicuous as a white patch on the face of the ridge. The quarry property is owned by Henry McGurk of Saratoga Springs by whom it was last worked about twenty years ago. It was operated mainly for paving blocks which were used in the streets of Albany and Brooklyn, but some building material was sold of which a specimen structure may be seen in the Hathorn vault in Saratoga Springs.

The quarry face lies about 80 feet above the base of the ridge and is 100 feet long. The stone has been quarried back for 60 feet or more. Apparently the granite was shot down in large masses which were then broken up and trimmed into paving blocks on the spot. A large amount of waste had accumulated on the quarry floor to the obstruction of the progress of development. The rock is traversed by two series of joints of which the more prominent has a course about N. 25° E. dipping 80° northwest, and the other about N. 60° W. with a dip of 80° northeast. There is also a series of division planes inclining about 40° to the south, parallel to which a faint lamination can be seen in the granite owing to parallel orientation of the biotite scales. It is said to have a good rift and grain so as to dress readily with even surfaces. Small bands of lighter granite are intercalated parallel with the lamination in parts of the quarry, and occasional knots or segregations of pegmatite and vein quartz are observable. There is, however, a good proportion of uniform material that could be used for building stone.

The granite is medium gray with very little of the dark silicates, which are limited mainly to biotite. Garnet in the form of grains and aggregates of grains up to an inch across is a subordinate but rather conspicuous constituent. The texture is compact, and the particles of quartz and feldspars average between 1 and 2 mm in diameter, the rock thus belonging to the fine-grained granites.

Microscopic examination. The feldspar consists of orthoclase, microcline and oligoclase, all of which show some alteration to sericite which impairs the quality of hardness. The particles are broken and angular and show strain shadows, evidencing the intense compression the rock has undergone. The quartz fills in the interspaces and is also granulated. The biotite occurs in small scales, which here and there have been converted into chlorite. Iron ores occur very sparingly. The granite may be considered as a fair material for crushed stone or paving blocks and well adapted for all foundation work.

GRANITE AT HORICON, WARREN COUNTY

An occurrence of granite at Horicon, on the outlet of Brant lake, Warren county, has supplied some building stone in an experimental way. It has not attracted much attention for commercial quarry purposes, owing to its remoteness from the railroad and difficulties of getting the material into the market. The present interest is mainly connected with the rather unusual nature of the rock which differs from that of normal granites.

The rock has a porphyritic appearance owing to the presence of pink feldspars, which measure up to an inch long and are rather thickly distributed through a groundmass of dark gray color which is composed of greenish feldspar, quartz and biotite. The large feldspars give an attractive pattern and a warm tone to the polished surface. They belong to the microcline variety and are developed in stout prisms that are usually twinned and occasionally granulated and squeezed into lenticular form. The greenish feldspar of the groundmass is a plagioclase identified as oligoclase. It forms rounded grains 2 or 3 mm in diameter. The biotite occurs in even smaller particles, but so abundantly as to lend a dark color to the body of the rock which, apart from the feldspathic constituents, has the character of a biotite schist.

The rock in fact is really a modified schist, the original of which, consisting of biotite and quartz with subordinate feldspar, has been drenched with solutions or vapors from a neighboring granite mass. The presence of the latter at least as an underlying body, is indicated by numerous pegmatite dikes, some of large size, that are exposed in the vicinity and that contain the same feldspar ingredients as the schist itself. In the vicinity of the dikes the granitic material increases in proportion to that of the original schist and the rock becomes lighter colored and coarser in grain. The groundmass is more or less recrystallized and largely absorbed. The impregnation of hornblende and biotite schists by granites is a common feature of Adirondack geology, but usually it leads to the formation of striped or leaf gneisses in which the original schist and the granite alternate in parallel bands. In the present instance, however, the added igneous material lacks any definite arrangement that might come from injection along definite planes, but is quite uniformly intermixed as if the impregnation had taken place with equal facility in all directions.

In consequence of the method of origin the rock varies in appearance and character from place to place, and there would be some difficulty in quarrying an even grade of product such as is required in building stone. It is a good material, however, for purposes of ordinary construction, in engineering works, foundations etc. Though it has not been tested for crushing strength, there is little doubt that it is fairly up to the average granite in that respect as well as in other physical qualities that make for durability.

Microscopically the rock appears quite fresh, except for incipient alteration of the feldspar which is somewhat sericitized. There are no sulphides; very little of iron oxides, with magnetite as the single representative; and no chloritic ingredients. Along with the secondary quartz and feldspar appears a notable amount of apatite in small prisms which is probably a pneumatolytic product incident to the granite invasion. The biotite is largely concentrated about the borders of the feldspar and quartz, as if it had been crowded out from the spaces occupied by the latter during their crystallization.

GRANITE NEAR GLOVERSVILLE, FULTON COUNTY

Gneissic rocks suitable for most purposes for which massive granite is used occur in the Adirondack Precambric area north and west of Gloversville. The boundary between the gneisses which form the Adirondack ridges and the Paleozoic sedimentaries at their base crosses Fulton county diagonally from northeast to southwest and is paralleled from Northville to Gloversville and Johnstown by the railroad which, however, is generally from 2 to 3 miles distant from the foot of the ridge.

The principal opening in the vicinity is the Edel quarry which is situated 3½ miles northwest of Gloversville and is worked by E. T. Edel of that place. It has supplied a large amount of architectural and constructional stone for the prosperous communities along the Mohawk river, having been operated more or less actively during the last twenty years. At present, building and curb stone are the principal products.

The rock is dark gray and though distinctly laminated shows little difference in appearance when cut parallel to or across the bedding. The grain is fine and compact, with some coarser particles of quartz and feldspar up to 3 or 4 mm in diameter scattered through the mass. The feldspar is mainly microcline. White quartz, biotite and a little hornblende are the other ingredients. There are no sulphides, so far as observed. The material is well adapted for all general construction purposes, as it is strong and no doubt as durable as any massive granite of similar composition.

GRANITE AT WHITE LAKE, ONEIDA COUNTY

A pink granite has been quarried to some extent near White Lake station on the Mohawk and Malone branch of the New York Central Railroad. It is a medium-grained, compact, slightly gneissoid rock with very little dark components which consist of scattered grains of garnet and minute flakes of biotite. It represents a rather massive phase of the granite gneisses that are of widespread occurrence in the western Adirondacks.

GRANITIC ROCKS IN THE HIGHLANDS SECTION

THE STORM KING GNEISSOID GRANITE

The prominence at the northern portal of the Hudson gorge, known as Breakneck ridge, is made up of a homogeneous gneissoid rock that is generally called the Storm King granite. There is little doubt of its granitic derivation, and the foliated appearance which it generally exhibits is a secondary character superinduced since its first consolidation. The granite is exposed over many square miles, forming one of the larger areas of that rock in the Highlands. From the characteristic members of the gneiss series in the vicinity it is distinguished by its greater uniformity of composition and appearance and its usually more massive structures, while it is also lacking in any marked banding or similarity to a bedded arrangement.

The granite area is limited on the north by a great unconformity that separates the Highlands Precambric crystalline formations from the less metamorphosed Cambro-Siluric strata of the Middle Hudson region. This break marks also an extensive fault. On the other sides the area is not sharply defined by topographic or structural features, and the granite gives way to gneisses which are for the most part laminated and more or less conspicuously banded and which include siliceous and calcareous members. The gneisses are of early Precambric age, the banded sedimentary types being classed by Berkey as Grenville. The relations of the granite to these gneisses have not been definitely determined, but it appears likely from what has been learned that its intrusion took place early in Precambric time among the first igneous invasions that are clearly demonstrated in the region.

In general the rock is a medium-grained, grayish or reddish, somewhat gneissoid granite. Parts of the exposure are thoroughly massive. There is a more or less marked tendency toward pegmatization; streaks, dikes and irregular bodies of reddish pegmatite are in evidence in most outcrops, and the granite itself shows coarser phases produced by disseminated crystals of the same red feldspar that occurs in the pegmatite. Inclusions of a dark hornblendic rock also occur. They may represent dikes which have been broken and crumpled, or perhaps are bands of the surrounding gneisses which have been caught up in the granite at the time of its intrusion.

Jointing is usually a marked feature, but is irregular in direction except in the case of shear zones which are not infrequent. In these zones the rock is usually too broken to afford much dimension material. The surfaces of the sheared granite show some decomposition and are often coated with chloritic minerals.

The granite from this area could hardly be quarried economically for architectural building stone, but is serviceable for foundation or rough work, as well as for crushed stone. For crushing purposes it is fully equal to the average granite, as the foliation is not sufficiently developed to affect its strength or to cause the stone to fracture readily in that direction.

Quarries on Breakneck ridge

Quarry sites are found along the south side of Breakneck ridge for a mile or more back from the river and in the past have yielded large quantities of constructional stone, paving blocks and crushed stone. Quarry work began here in the early part of the last century, probably before 1825. For the last few years the output has been intermittent and small.

The principal operations have been carried on at Bailey's quarry just east of the river and 100 feet above the base of the ridge. The quarry face extends 300 feet east and west and is quite 100 feet in height. The quarries were equipped at one time with a crushing plant which supplied material for highways and railroads but this has been dismantled. The quarry work itself has not demanded much equipment as the plan usually followed is to break down the stone in large blasts and to utilize the product for different purposes according to its quality and size.

Microscopic examination. The granite belongs to the hornblende variety, having a dark green hornblende as the ferromagnesian mineral. The other important ingredients are feldspar and quartz. The feldspar consists principally of microperthite and an acid plagioclase, and is sometimes intergrown with the quartz. There is a little magnetite but apparently no pyrite. The texture is even granular, compact, scarcely differing from that of a normal granite.

Quarries on Storm King mountain

There are quarries on the southeastern face of Storm King mountain, almost directly opposite those on Breakneck ridge. They were once worked for building stone and paving blocks, and Smock states that buildings in New York and Washington were erected from this granite. A few years ago the Storm King Stone Co. erected a large crushing plant here. No dimension stone has been shipped for a long time. The granite is very similar in composition and appearance to that on the east side of the river but carries some biotite as well as hornblende.

Old quarries, long since abandoned, exist on the south side of Crow's Nest mountain, and on the next ridge to the south which is partly occupied by the grounds of the West Point Military Academy. Some of the academy buildings are constructed of material from these quarries.

THE GARRISON GRANITE BOSS

King's quarry

A small area of massive granite is exposed north of Peekskill between Manitou and Garrison in Putnam county. It lies within the main gneiss belt that forms the more rugged part of the Highlands as exemplified in the Hudson gorge section from Anthony's Nose to Breakneck ridge on the east bank. The area is about one-fourth of a mile back from the river and 2½ miles from Garrison, a station on the New York Central and also a point for river shipment.

The outcrop appears to have the structure of a boss which has cut through the country gneisses but has not shared in their extreme metamorphism. The gneisses are Precambric and probably belong to the earlier or basal division of the series represented in this region. From the field associations the age of the granite intrusion can only be indefinitely fixed, with a probability in favor of late Precambric or early Paleozoic times. The proximity of the Cortlandt series, which is only a few miles to the south, as well as the existence of a granitic facies among its highly differentiated representatives, might be regarded perhaps as suggestive of some relation with that invasion which took place as late at least as Siluric time.

A comparison of the Garrison and Peekskill granites shows that they resemble each other only in regard to color and their uniformly massive habit. The former is a representative of the normal alkali class of granites characterized by a preponderance of the potash feldspar over the lime-soda varieties; the Peekskill rock on the other hand shows by its high content of plagioclase an affinity with the diorite-gabbro series and, strictly considered, is to be classed as a quartz monzonite. The Garrison boss, also, is distinguished by a fine cataclastic texture, while the samples of the Peekskill granite seldom show any appreciable effects of pressure metamorphism. These features point more or less clearly to a separate, independent source of the two intrusives and the prior age of the Garrison boss.

The granite has been quarried quite extensively for building stone and foundation material, for which purposes it is very well adapted. The main opening is known as King's quarry, operated at one time by the King Granite Co., and later by Doern & Sons of New Rochelle.

Some of the buildings erected from material secured at this quarry are: St Joseph's Church, Tremont av. & Washington st., New York; Guard House at West Point; powder magazine on Iona island in the Hudson river; and a school building in Tarrytown. The property has not been worked extensively for the last few years and probably will not again be a very active producer. The granite boss, however, extends out on the adjoining lands, so that other quarries may be operated in the future. A site already prospected is found just south of King's quarry on the land of Raymond Moore of Peekskill.

Field characters. The general structure and quality of the granite are best shown at King's quarry which covers perhaps half an acre of surface and has a face up to 50 feet high. The principal structural feature is lent by the jointing which is well developed, especially the sheet joints. The latter divide the exposed rock into elongated horizontal lenses that are from 1 to 3 feet thick in the middle but increasing in size as depth is attained. The sheets are inclined slightly toward the northwest. Three sets of steeply inclined joints also occur, of which the most prominent strikes north and south and dips 70° east; another set strikes N. 40° W. and dips 70° southwest; and the third strikes east-west and dips 60° north. The rift is stated to be about parallel with the first set.

In physical appearance the granite is characterized by a fine grain, medium gray color of body that is well blended, and massive to faintly gneissoid texture. Small crystals of garnet are sparsely scattered through the mass but are noticeable only on close view. There are few streaks or discolorations apparent in the exposure.

Microscopic examination. The rock consists essentially of feldspar, quartz and biotite in order of importance, with garnet as an accessory which has probably been formed by a partial recrystallization of the minerals caused by compression exerted upon the boss after its intrusion. The feldspar and quartz are in irregular particles closely interwoven. Their average diameter is about 5 mm. The biotite is in very fine beds, sprinkled like dust through the gray groundmass. The texture is close and firm.

The feldspar minerals include microcline, microperthite and orthoclase as representatives of the alkali class and an acid plagioclase which has subordinate importance to the others. They are but little altered. The biotite is somewhat bleached or partly changed to chlorite. The absence of pyrite or other igneous ingredients is noted.

Physical tests. The granite from this quarry has a specific gravity of 2.68, ratio of absorption .3 per cent, and pore space .792 per cent.

ROUND ISLAND GRANITE

Round island, in the Hudson just above Peekskill, is made up of granite which at one time was actively quarried for crushed stone. The quarry was worked up to ten years ago by Daniel Donovan of Kingston. The site of the quarry was not visited by the writer and there are no details available as to the character of the stone aside from the following chemical analysis, supplied by Mr Donovan:

SiO_2	63.19
Al_2O_3	10.50
Fe_2O_3	10.97
FeO	1.51
CaO	6.12
MgO	1.44
K_2O	4.02
Na_2O	1.92
Loss	.18
Undet.	.15
	100.00

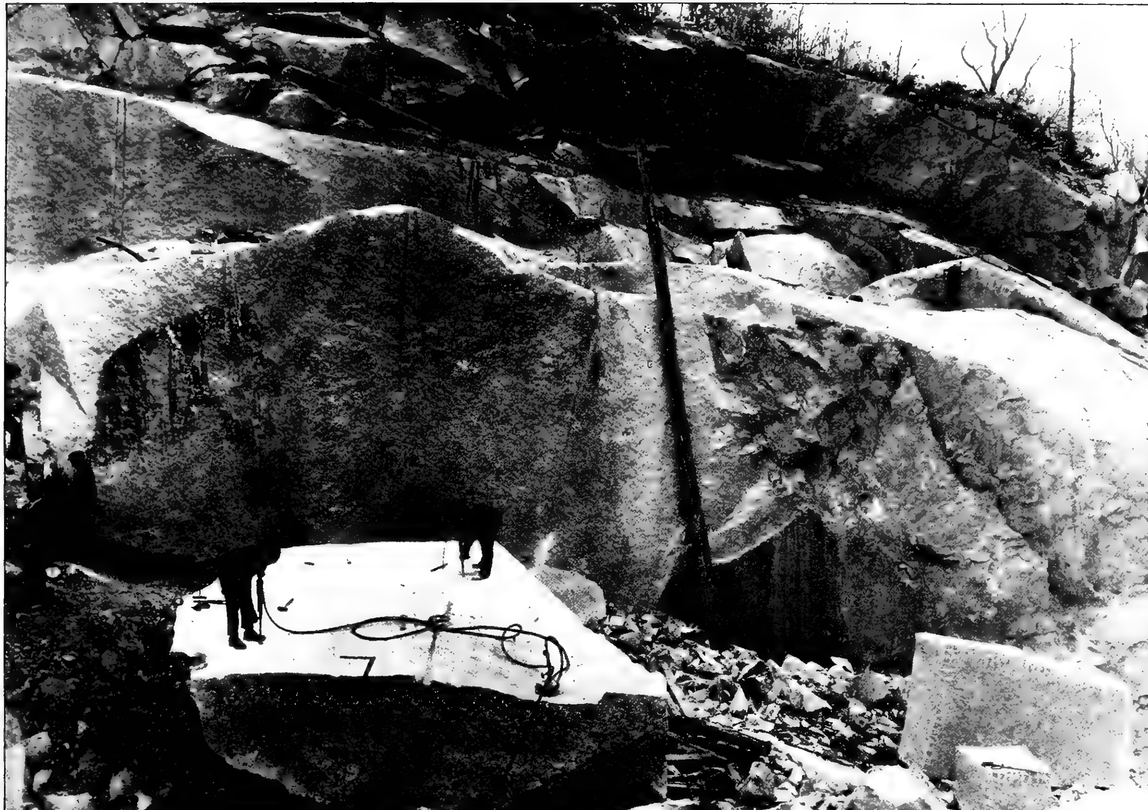
THE PEEKSKILL OR MOHEGAN GRANITE

Granite intrusions are found on the borders of the area occupied by the Cortlandt series, which is the name given to an interesting group of basic igneous rocks exposed to the south and east of Peekskill. The Cortlandt series comprises diorites, gabbros, norites, pyroxenites and other types of basic habit, with such relationship as to indicate that they represent the differentiated products of a single deep-seated magma. Their intrusion took place probably as late as Siluric times since the series breaks through and includes portions of the metamorphosed sediments that are classed with the Hudson River series of the Lower Siluric. Their outcrop extends over an area 5 miles in east-west diameter and about 4 miles from north to south, in outline an immense boss.

The granite exposures are on the north side of the Cortlandt area and immediately adjacent to it. The first outcrop encountered on the west is a mile or so out of Peekskill on the little knob lying between the Lake Mohegan road and the east-west highway, just west of the line of the Catskill Aqueduct. The locality is known as the Roberts quarry. Millstone hill, which lies a mile farther east and south of the east-west highway, is made up in its northern slopes of granite, but is apparently near the contact with the basic rocks of the Cortlandt series which appears on the next prominence to the west. A third place where granite appears in force is across the valley from Millstone hill, on the south and west slopes of a ridge, about a mile south from Lake Mohegan. The Mohegan Granite Company has quarries at this locality.

In the several exposures which embrace between them an area of 3 or 4 miles, there is naturally some variation in the appearance and composition of the granite, though as a whole the samples from the different quarries exhibit a degree of uniformity which would seem to establish their identity with one and the same intrusive mass. This uniformity is reflected in the predominance of white feldspar, mainly orthoclase, albite and oligoclase, which gives a light tone to the rock wherever exposed, in the presence of both biotite and muscovite, a moderate to small content of transparent quartz, and in the granitic texture which ranges from medium to fine grained. It appears probable that the different quarries are located on outcrops of a single body which has the Cortland series on the southwest and lies against the metamorphic rocks, including Paleozoic schists, on the remaining border. The exact extent and shape of the mass is somewhat indefinite, as there is a heavy cover-

Plate 18



Part of the Mohegan Granite Company's Quarry, Peekskill

ing of soil and detritus over the low ground that intervenes between the exposures.

Owing to the prevalence of plagioclase among the feldspars represented, the Peekskill granite shows a relatively high proportion of soda as compared with most granites and appears to be genetically allied with the diorites of the Cortlandt series. This feature, as well as the field relationships already mentioned, lends support to the view expressed by Berkey[1] that the granite represents but a phase of the Cortlandt invasion and not a separate body; it constitutes the acid extreme of the series which in the other direction range through diorite, gabbro and norite to rocks like pyroxenite and peridotite that are destitute of quartz and feldspar.

The granite like the typical Cortlandt rocks, is thoroughly massive in texture, lacking evidences of strong compression and the gneissoid development which are so common among the Precambric and early Paleozoic rocks of this section. Its intrusion occurred therefore after the period of regional metamorphism that marked the close of Lower Siluric time — the last stage in the general metamorphism of the region. The contact of the granite with the country rocks is very generally concealed, but inclusions that apparently represent the bordering schists are not infrequent and sufficiently establish the nature of the contact relations in that respect. The latest of the country schists belong to the Hudson River series. The inclusions mostly in evidence are amphibolites and dark hornblende schists which undoubtedly came from some of the earlier and underlying formations.

The view expressed as to the common derivation of the granite and the Cortlandt rocks can not be supported by observations in regard to their mutual contact relations, as such information was not procurable when the writer visited the locality. There seems to be complete similarity, however, in their attitude with respect to the crystalline schists, and the field evidences, so far as they go, are indicative of a geologically contemporaneous intrusion for both granite and gabbros.

Mohegan Granite Company's quarries

The quarry property of the Mohegan Granite Company is situated a little east of the Cortlandt township line in Yorktown, Westchester county, on the southwestern slope of a prominent ridge

[1] Science, 28: 575, 1908.

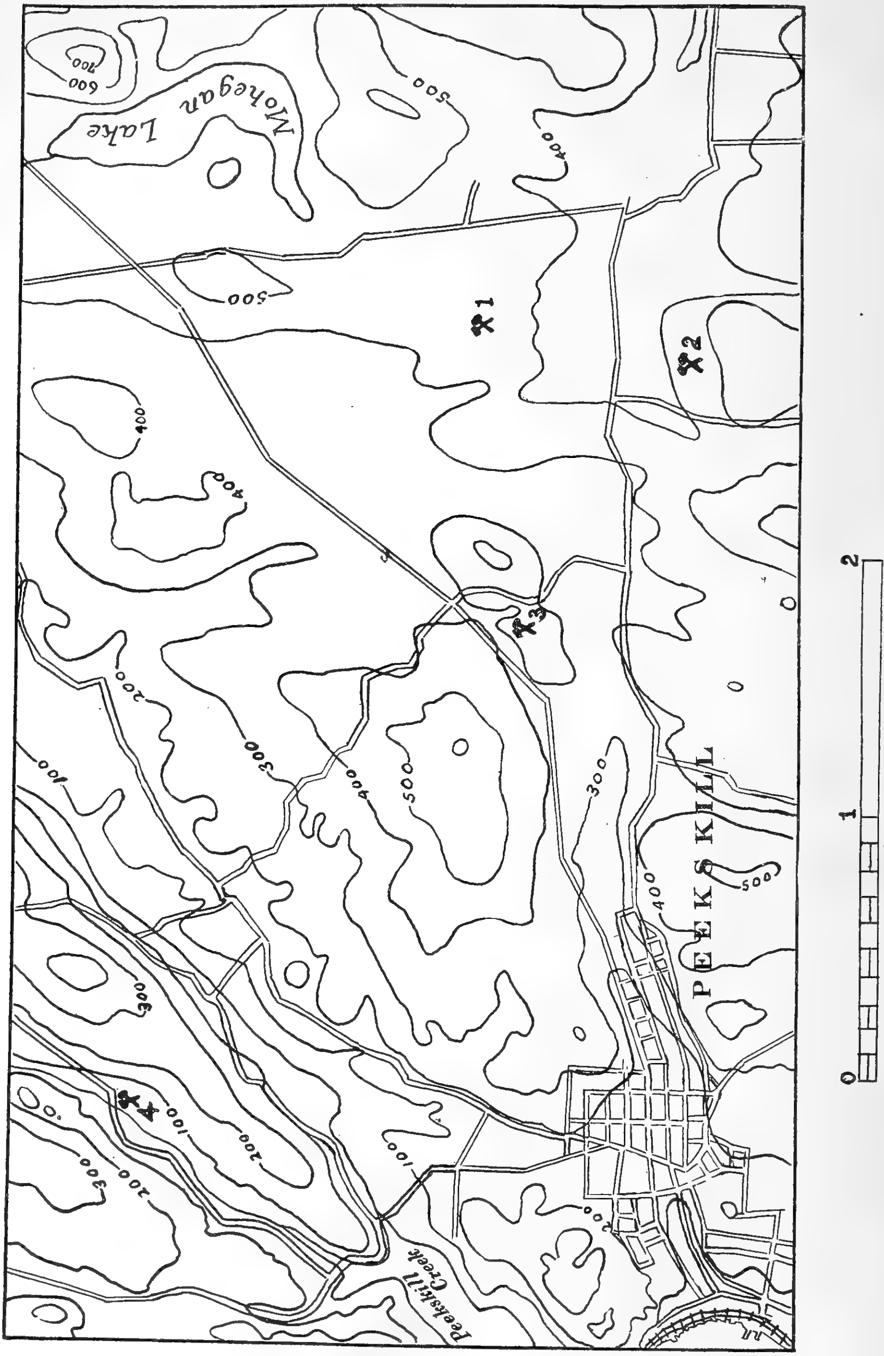


Fig. 10 Map of the quarries near Peekskill. 1 is Mohegan; 2, Millstone; 3, Roberts quarries, all in granite; 4, Frost quarry in crystalline limestone

which extends northward past Mohegan lake. The workings lie between 400 and 500 feet above tidewater at Peekskill and 5 miles distant by the highway. Regular quarry operations date from 1892 when the granite was wrought by E. P. Roberts for the construction of the dams at Carmel and Purdy station in connection with the New York water supply. The granite was later selected, after an extended search for material adapted to the purpose, for the construction of the Cathedral of St John the Divine, the largest church edifice in America, and during several years the quarries have been engaged in supplying cut stone for that structure which will require shipments for some time to come. It has been used also in other buildings in New York, including the residences of Charles M. Schwab on Riverside drive and of Clarence W. Bowen on 63d street, the Postal Telegraph Building on lower Broadway, the Cross Building on Fifth avenue, and several of the houses in the Bronx Geological Gardens. It has also found considerable sale for monumental work, examples of which may be seen in many of the larger cities of the east.

The quarries furnish two varieties of the granite, a light gray of more or less pinkish hue and a rich yellowish brown that is almost a golden yellow when seen at close range. The yellow granite has no match in beauty and uniformity of its color among eastern granites and its warm, subdued effect in buildings has won favor wherever the stone has been introduced. The light gray color is characteristic for the Peekskill granite as a whole and occurs below the yellow at varying depths, but usually the change occurs at or about 40 or 50 feet. The color variation so pronounced at these quarries seems to be purely local, the yellow granite occurring nowhere else and being the result, as later explained, of secondary influences at work since the consolidation of the intrusion and its exposure at the surface.

The quarry openings extend over a distance of several hundred feet on the hill slope, which falls off rather steeply to the west. The thin soil covering supports a moderate forest growth and serves to conceal the outcrop over much of the undeveloped ground. The granite is known, however, to cover an extensive area. The principal quarry is at the south end, and runs northeasterly for 300 feet, showing a face against the hill of about 40 or 50 feet. This quarry is served by a short inclined tramway on which the cars are raised and lowered by a cable. The granite has a slightly sheeted structure, the sheets dipping 15° or 20° west. There are two principal joint systems, one vertical with a strike of N. 70° E., and the other inclined 80° or 90° and striking N. 30° W. The rift is about north-south and nearly vertical. The joints are irregularly spaced, usually at fairly wide intervals, but in one place form a heading where only material for crushing purposes is secured. Dimension stone of almost any merchantable size can be quarried.

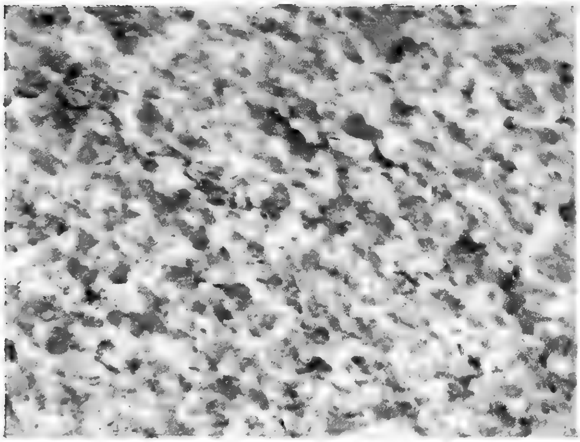
Knots and streaks are rare and dikes apparently absent. There are occasional inclusions of the country schists, the larger ones being on the northwest and east sides of the quarries. A conspicuous example which is found on the north side of the incline consists of black hornblende schist that has been injected by granite and pegmatite and forms a vertical wall for a short distance, wedging out finally in the granite which apparently surrounds it completely.

The quarries are equipped with modern machinery for breaking, hoisting and cutting the granite, but as yet are scarcely developed to the stage that admits the most advantageous operations. The stone is mostly dressed on the ground. The cost of haulage by wagon to Peekskill makes that necessary. Increased facilities for cutting have recently been provided by the erection of a steel-frame shed of dimensions 130 by 50 feet. The capacity for turning out finished material is thereby more than doubled. The equipment at the quarries includes a 50-ton crushing plant for working up the waste material.

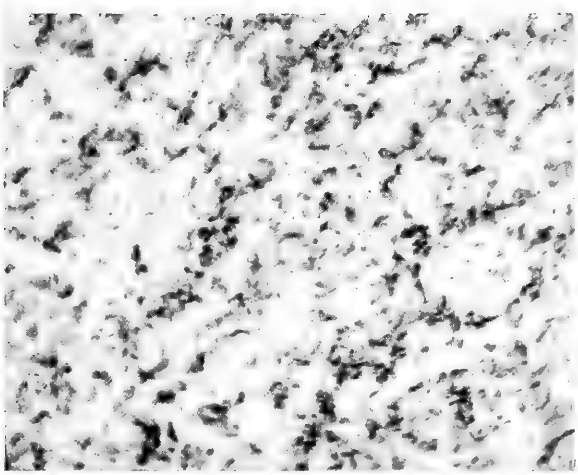
Microscopic character. The granite from this locality belongs to the medium-grained class, inclining toward the finer end of the scale. It is a mixture of feldspar, quartz and mica in their order of abundance. The feldspar and quartz are mostly under .25 cm in diameter, the quartz individuals occasionally slightly exceeding that limit. The mica includes both biotite and muscovite and is so finely divided and evenly distributed as to be little noticeable except against the white background of the light gray granite. The feldspars include albite, oligoclase and subordinate orthoclase, all of which show incipient alteration by their clouded appearance under the microscope. Chlorite is sparingly present as an alteration product of the biotite. The accessory constituents include magnetite, zircon and apatite in very small amounts.

The yellow or golden hue characteristic of the superficial part of the granite is due to the presence of a little limonite stain distributed along the borders and microscopic cracks of the quartz and feldspar, particularly of the quartz which seems to carry most of the coloring matter. The stain is not accompanied by any marked softening or decomposition, contrary to what might perhaps be expected, for

Plate 19



Mohegan yellow granite. Peekskill



Mohegan gray granite. Peekskill

the granite when examined microscopically appears little more weathered than the gray variety. The apparently even distribution of the coloring matter when the rock is viewed in the mass disappears on closer examination and the stain is seen to be developed in flecks and lines scattered over a white background of feldspar and quartz. Most of the limonite is found in the quartz which is the ingredient that shows the most granulation and consequently the

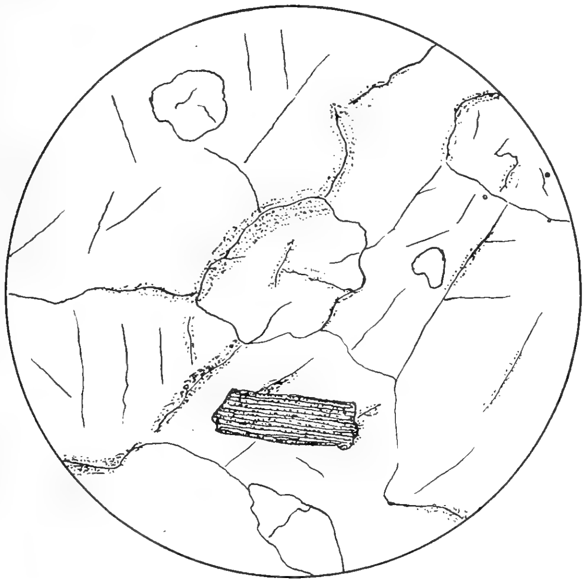


Fig. 11 The yellow Mohegan granite, showing concentration of limonite along the borders and in the cleavage cracks of the mineral particles

most open space for its deposition. The source of the limonite is traceable to iron-bearing solutions from the surface which found their way downward along the joints and then diffused through the rock by means of the capillary openings. It may have been derived from decay of the overlying rock in the long period of exposure previous to Preglacial time, but of such a zone of disintegration there is no remaining evidence at present and is hardly to be expected after the erosive work of the ice. The limonite often seems to be concentrated about the biotite, but this is not a result primarily of a chemical alteration of that mineral, but rather arises from the infiltration of the iron along the cleavage planes of the biotite. Much of the biotite is perfectly fresh, showing no bleaching or other change that could result in freeing any of the iron. In some of the sections examined a small proportion of the flakes showed partial or complete change to chlorite. The amount of iron set free from the biotite in any case is entirely insufficient to produce the present color.

Chemical and physical features. The following data in regard to the granite was supplied by the Mohegan Granite Co. in 1904 in response to the request from this office. The tests were made on four separate samples in the laboratories of Ricketts & Banks. It was not specified whether they were based on the yellow or the gray variety.

Sample	Iron per cent	Sulphur per cent	Specific gravity	Crushing strength lbs. a sq. in.
1	.34	.015	2.64	21,979
2	.86	trace	2.62	19,303
3	.30	.022	2.64	12,547
4	1.15	.015	2.67	16,889

The lower crushing strength of no. 3 is accounted for by a defect in cutting the sample which resulted in the loss of a chip from one corner. The tests evidence the physical soundness of the granite and confirm the results of quarry and microscopic examinations. The weathering qualities of the granite are considered excellent. The pyrite content as indicated by the sulphur percentage is too small to have any influence.

A sample of the light gray granite tested by the writer had a ratio of absorption of .319 per cent and pore space .829 per cent. The yellow granite showed a ratio of absorption .368 per cent, pore space .962 per cent.

An analysis of the granite from this quarry by Elwyn Waller is given herewith:

SiO_2	73.32
Al_2O_3	15.01
Fe_2O_3	.47
FeO	1.19
MgO	.15
CaO	1.35
Na_2O	4.27
K_2O	3.72
H_2O+	.13
TiO_2	.06
MnO	trace
Total	99.67

Millstone Hill or Cornell quarry

The largest opening in the Peekskill granite is on Millstone hill south of the highway leading east from Peekskill and adjacent to the line of the Catskill Aqueduct. It is across the valley and a mile distant from the Mohegan Granite Company's quarries, in Cortlandt township. The main development of the property resulted from the operations by Coleman, Breuchaud & Coleman, the contractors for the new Croton dam which was constructed entirely from material secured at this place. The quarry has furnished also some stone for buildings in the vicinity, notably the Drum hill school at Peekskill. It has been idle for the last few years, but recently has come into the control of Rudiger Brothers who aim to reopen it.

The quarry lies east and west on the ridge, about 150 feet above the highway. The lower ground is heavily covered with soil and drift. The excavation measures about 500 feet long and 200 feet wide in extreme dimensions and has been carried downward to a depth ranging from 30 feet on the north side to 75 feet on the south. No hoists or other equipment are standing on the property. In the period of operation the stone was transported on a tramway to the Croton dam, but the road has been torn up. The outlet is by way of Peekskill to the railroad or the Hudson river, involving a haulage of about 4 miles.

In the quarry the granite shows the characteristic massive structure; joints are rather wide apart and irregularly spaced, except on the west end where they form a heading. The joint systems include a north-south series which dips 80° west and an east-west vertical series. Horizontal division planes have little persistence, hardly justifying their reference to sheeting, though there is some tendency toward division on planes dipping slightly south and west. The rift is reported to run parallel with the north-south joints. No dikes or large inclusions are observable in the quarry walls.

At this quarry there is no capping of yellow granite, so prominent in the Mohegan property, and the only suggestion of any color change consists of a slightly mottled effect produced by a little limonite stain around the biotite crystals, like the rust on iron. This is apparently the initial step in the transformation from gray to yellow. The granite from the deeper parts of the quarry, however, is entirely free of limonite with a very uniform body that appears almost white. The quality is excellent for all architectural purposes.

Microscopic character. Feldspar is first in importance as a constituent and consists mainly of albite or acid oligoclase with subordinate orthoclase. The individual crystals often show marked zonal structure. Alteration is evidenced by clouding and the development of muscovite and probably also of kaolin. The quartz is slightly gray or smoky in color. Of the micas, muscovite is equally common with the biotite variety and occurs in original crystals, as well as secondary growths from feldspar. The biotite shows partial change to chlorite. Iron ores are very scarce except for the little limonite that occurs in the exposed part of the granite. The grain may be classed as medium, the coarser particles of feldspar and quartz attaining a diameter of 10 mm. The interspaces are filled up with finer interlocking individuals and the texture is very compact.

Crushing strength. A crushing test performed by Ricketts & Banks on a sample from the quarry, as communicated by J. M. Rudiger, showed an ultimate strength of nearly 21,000 pounds to the square inch. The details are as follows: size of cube, 1.99 by 2 by 1.99 inches; area 3.98 inches; breaking strain 83,100 pounds; ultimate strength 20,870 pounds a square inch. The granite is unquestionably strong and durable.

Roberts quarry

An exposure of granite occurs in the knob lying just southeast of Jacobs hill and between the Peekskill-Lake Mohegan road and the Catskill Aqueduct. It is more than a mile west of Millstone hill. The knob is of small compass, a few hundred feet in diameter and less than 100 feet high. It has been opened on the southeastern side to supply stone for local construction. The quarry is only about a mile out of Peekskill and appears to be located at the most accessible point of the granite area.

The quarry cut is about 100 feet long, with two small-sized derricks in place. The granite is well jointed along two directions, N. 60° W., and N. 20° E. but is not sheeted.

The stone differs considerably in texture and appearance from that exposed in other parts of the area, but the general composition, so far as the nature of the mineral ingredients are concerned, is similar. It has a coarse grain which is made very prominent by the large micaceous aggregates of dark color, whereas the body of feldspar and quartz has the usual light hue. These aggregates formed by intergrowing muscovite and biotite attain a diameter of half an inch; they are oriented parallel with the rift, and to surfaces cut in that direction lend a mottled aspect. The quartz and feldspar are in granulated condition, probably the result of compression upon what originally were large crystals but are now finely comminuted. There is some limonite stain in zones about the mica.

The granite at this quarry appears darker when observed in mass than the average of the other quarries. It would be classed as medium gray, with a pinkish tone, the pink being fairly decided in places.

As a variant of the Peekskill granite boss may be mentioned an outcrop which lies but a few rods to the east of the Roberts quarry and undoubtedly is a part of the intrusion. It is characterized by the abundance of mica, much greater in amount than observed in the rock elsewhere. The color as a consequence is quite dark. From microscopic examination the feldspar appears to be almost entirely plagioclase and to predominate largely over the quartz. The rock by itself would be classed as a granodiorite, and the occurrence serves to bring out the close relation that probably exists between the granite and the more basic types which constitute the Cortlandt series proper. The ledge is too small to have any importance for quarry purposes.

THE YONKERS GNEISSOID GRANITE

A light-colored granite with a markedly foliate texture is found in southern Westchester county where it is the basis of rather extensive quarry operations. Under the name of the Yonkers gneiss it has been described by Merrill and others and its igneous derivation clearly established. The fact, however, that the foliated appearance in the main is not the result of secondary recrystallization or metamorphism, but an original feature imparted during the first consolidation of the magma has not been generally recognized. On account of this fact it seems more appropriate to call the rock granite than gneiss, the latter term implying, as it does, the effects of metamorphism.

According to the recent work of Berkey, the Yonkers is probably to be classed with the early Precambric series of intrusions which are represented in the Highland region by the Storm King boss. It seems to be confined to thin sills which are intrusive in the Fordham gneiss. The development of the parallel arrangement of the constituents may be explained as the effects of compression exerted during the intrusion of the granite while it was still in a condition of mobility, facilitated by the relatively thin mass of the granite. There is little in the way of secondary crystallization as seen in acid gneisses. Examples of what appears to be crushed and sheared gneiss are frequently observable in the field but they are probably the result of viscous flowage of the magma.

The granite outcrops in several areas. The principal belt within which most of the quarries are situated parallels the Bronx river and Harlem Railroad from a point a little south of Mount Vernon to Hartsdale, near White Plains. The outcrop lies along a series of hills and ridges between the Bronx and the parallel valleys of Tibbitt and Troublesome brooks. Its surface shows only moderate relief, the highest elevations slightly exceeding 300 feet, with intersecting notches and cross-valleys whose bottoms mostly are between 100 and 200 feet. The main intrusion is nearly 10 miles long, but not much over one-half of a mile wide. This form doubtless results from a sill or sheetlike intrusion of the original granite which penetrated the sedimentary formations of the Fordham along the bedding planes and has since been upturned so as to afford a longitudinal section.

A second area of the Yonkers occurs along the axis of the main belt farther north, near Valhalla and the Kensico reservoir. This has not been so actively worked as a source of building stone. There are a few quarries, however, that have been operated at different times, mainly to supply foundation material, including that used in the Kensico dam.

General characters. The Yonkers granite varies more or less in physical structure and appearance. This observation applies even to the limited area of a single exposure, where occasionally the characteristic thinly foliate rock may be seen grading over into a quite massive one. There is little variation, however, in respect to the mineral composition, and the whole rock mass is quite free from segregations and inclusions. The quarry sites in most instances have been selected with a view to uniformity of the material which is obtainable to a fair degree. Eckel[1] describes the general features of the Yonkers as follows:

The color of the Yonkers gneiss varies from a light blue to a rather deep red. This variation is partly due to the fact that the blue grades in most cases contain more quartz and less feldspar. A much more potent cause, however, is that the feldspars themselves are either red or bluish. This difference in color is not due to a difference in the feldspar species, as the microcline and sheared orthoclase appear in both the red and blue Yonkers, and in about the same relative proportions.

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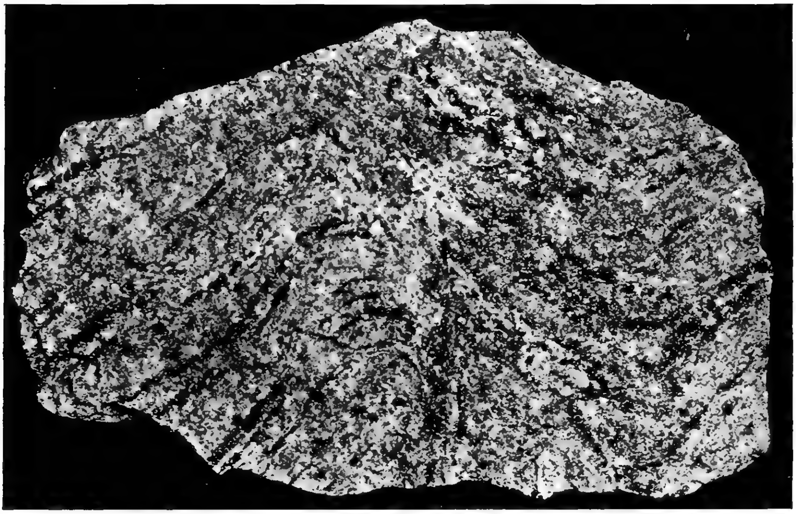
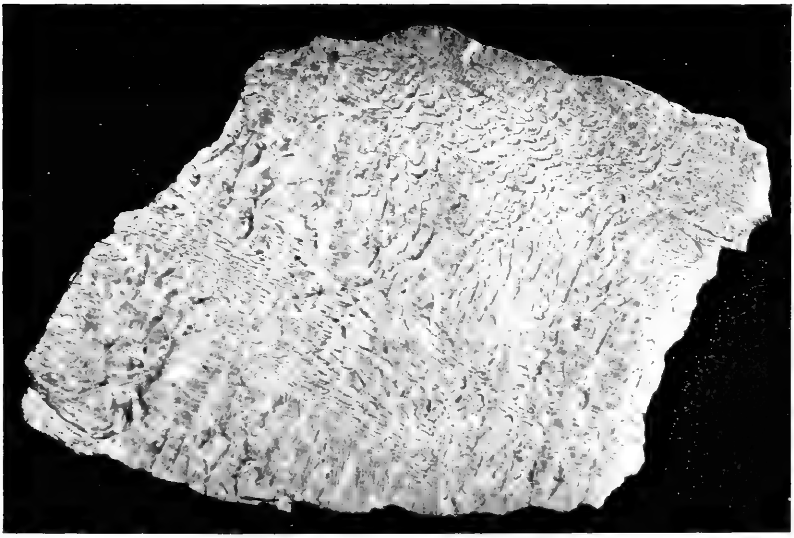
[1] The Quarry Industry of Southeastern New York. N. Y. State Mus. Rep't 54, 1902, p. 155.

Plate 20



Yonkers gneissic granite, showing plastic yielding and flowage. Kerbaugh quarries, Kensico.



Graphic granite, an intergrowth of quartz and feldspar. From Bedford, Westchester county.

The difference of color is of importance economically. The red forms decay rapidly, while the blue, though often becoming stained yellow by iron, do not appear to disintegrate. The writer has not been able to follow up this investigation as far as he could have wished, and the discussion in this paper should be regarded as merely preliminary to a more detailed presentation of the subject.

The inference in the above quotation that the color variation has significance with respect to the durability or weathering qualities of the granite claims attention, though no explanation is vouchsafed in the paper. The present study has not afforded any clear evidence of such relationship. There is apparently a wide difference in the capacity of the granite to withstand disintegration, but this feature seems more related to the textural characters than to any peculiarities of the mineral constituents that are reflected in the color.

Some natural surfaces are practically fresh, though they have been exposed to atmospheric conditions since Glacial time. In other places the granite is disintegrated to some depth. The first stages of weathering are usually manifested in a weakened cohesion of the mineral particles, as the result of the alternate expansion and contraction under varying temperatures. The microscopic cracks and pore spaces are enlarged with the progress of weathering. The final stage of this physical disintegration is reached when the rock becomes a loose, mealy aggregate of quartz, feldspar and mica. Chemical decay, of course, accompanies the physical breakdown and is first evidenced in the separation of iron oxide and the softening of the feldspar, but it is mainly effective after the rock has undergone partial disintegration.

It is evident from a study of the granite in the field that the texture has much to do with its weathering qualities. The types which are characterized by a closely knit fabric, with the individual grains well interlocked, as observed in most unchanged granites, are resistant to weathering. Such textures are found in the massive varieties of the rock and in the foliated types which have not undergone noticeable granulation from shearing action. The granular even-textured types, on the other hand, are apt to be of more porous nature and more prone to disintegrate.

The Yonkers is quite free of knots and streaks arising from irregular mineral distribution. The principal variation relates to texture and grain. Coarse, massive phases occur here and there as a kind of pegmatitic development. Some exposures are only moderately foliated. The characteristic rock, however, is thinly foliate, with the biotite interleaving the quartz and feldspar at regular intervals.

The granite, with the exception of the very granular sorts as noted above, is a serviceable stone for all general construction purposes. It has no ingredients to cause discoloration or decay with the lapse of time. Its durability, when subjected to mere weathering, can scarcely be inferior to ordinary granite, though of course it has not the same ability to withstand abrasion or wear, on account of its tendency to cleave along the foliation planes. The many buildings in Yonkers and vicinity that have been constructed of this stone are evidence of its good quality as a structural material.

Microscopic examination. The mineralogy of the granite is simple; feldspar, quartz and biotite are the components in order of their relative importance. The feldspar is divided between orthoclase and microcline, with a little plagioclase. The quartz has a bluish tint and with the biotite often lends a decided bluish cast to the cleavage surfaces, whereas the color across the foliation is prevailingly pink, like that of the feldspar. Under compression, the quartz has developed into lenticular or spindle-shaped individuals, while the feldspar has been corroded and broken down into small irregular particles.

The subordinate constituents include hornblende, iron oxide, titanite, and zircon. Sulphides appear to be absent from the mass of the rock. There is little change noticeable in the thin sections, except a slight kaolinization of the feldspars and separation of small amounts of iron from the biotite.

The rock is fine to medium in grain. The lines of foliation marked by the biotite are mostly spaced from 4 to 10 mm apart.

Quarry development. Quarry work in the Yonkers belt has been carried on for a long time, but until about twenty years ago did not reach any considerable proportions. Eckel states that most of the quarries operative at the time of his report were opened around 1892. At that time, and in the few subsequent years, there was unusual activity in building and engineering construction, particularly by the railroads, which had a great deal of work in connection with bridges and retaining walls under way. The market for stone, however, was mainly local, and with the completion of these improvements the demand so declined as to compel the closing of many quarries. The present outlet is principally for building stone, as illustrated by many public and private structures in Yonkers and vicinity, also in partly dressed condition for foundation work, and as blocks and crushed stone for road improvements.

A number of quarry sites mentioned in the earlier descriptions of the industry by Smock and others have been converted into building plots or otherwise utilized so as to exclude their further exploitation for stone. Some of the more important of the old quarries, not now worked, will be mentioned here for the purpose of record.

The Valentine quarries are described by Mather as operative at the time of this report (1842) and are also referred to by Smock. They were situated 2 miles southeast of Yonkers, on the Mount Vernon road. They were worked at intervals when Smock made his report and have since been abandoned.

A quarry on the Stewart estate, near Dunwoodie, was worked for several years by O'Rourke Brothers of Yonkers. It supplied rough and cut building stone and crushed stone. Production ceased in 1908.

The McCabe quarry in the town of Scarsdale, about a mile east of Hartsdale, was opened in gneiss similar to the Yonkers, but lying off the main belt. The output was mainly crushed stone, with some rough foundation stone. The quarry has been idle for about ten years and will not again be worked.

An unnamed quarry, situated about an eighth of a mile north of the preceding, in the town of White Plains, near the Cambridge road, was operative a few years ago, but has now been permanently abandoned. It produced rough and cut building stone and road material. There was much waste, owing to pegmatitic admixture and the closely spaced joints. The opening was 400 feet long, exposing 40 feet of a light variety of gneiss, not distinguishable from the Yonkers in its characteristic occurrence.

A small quarry once existed in the town of North Castle, about a mile northeast of Silver Lake, and was known as the Collins quarry. The rock, according to Eckel, was reddish foliated gneiss of the Yonkers type. Production was restricted to local needs and it has been closed in recent years.

The quarry once worked by Dennis Cahill and situated on Reidland avenue, east of Central avenue, has been permanently closed.

The Flannery quarry in the same vicinity has produced a small quantity of stone in recent years, but will not be worked in the future.

The Seely quarry, one-half of a mile west of Scarsdale, has been abandoned many years and probably will not again be worked.

The Ferris, Dinnan and Outlet quarries are old openings in the body of Yonkers gneiss near Valhalla.

Hackett quarry

Hackett Brothers, of Yonkers, have operated a quarry for several years in the northern part of the main Yonkers belt. Their property lies about a mile north of Dunwoodie, at the junction of Midland and Central avenues, and is opened for a distance of 800 feet along the course of the gneiss.

The working face is about 40 feet high. The quarry has furnished a large amount of building stone, which is its chief product. Some of the larger structures in which the stone has been used are: St Joseph's Seminary, Dunwoodie; Seton Hospital, Spuyten Duyvil; St Joseph's Hospital, Yonkers; St John's Hospital, Yonkers; St Dennis Church, Lowerre; and public school buildings Nos. 3, 9, 10, 15, 18, Yonkers. Polished examples are shown in the columns of the county jail at White Plains.

The rock is characteristic Yonkers, rather fine in grain and of bluish color, as seen in the quarry ledge. This color becomes more of a pink on the cleavage surface of hand specimens, owing to the fact that the colored feldspars are much pressed out along the foliation. The hammer-dressed surfaces are a medium gray. The stone is free of spots and discolorations.

The gneissoid foliation at this locality is quite regular in direction and character. The strike is N. 30° E. and the dip vertical or slightly turned to the west. Horizontal joints are well developed, at an average of from 3 to 5 feet apart, permitting bench operations. A second system of joints parallels the foliation, and the third strikes N. 65° W. and dips 80° W. The structure is well suited to the production of dimension stone. The rift, of course, runs with the foliation.

In quarrying, the stone is broken out by black powder. Holes are put down about 10 feet by a steam drill. This method naturally yields a large quantity of material unsuited for building stone and this finds sale for rough foundation work, particularly in macadam and telford roads. There are two derricks in place. The average force is about ten men. Shipments by rail are made by the Putnam division of the New York Central Railroad.

Perri quarry

A quarry, operated by Louis Perri, is situated on the east side of Central avenue, across from the Hackett property. It is just west of the site of the old O'Rourke quarry, now converted into building lots. The opening at this place is about 100 feet long and affords a face about 30 feet high, practically unweathered to the surface.

The rock is uniform in color and grain, representing a good quality of the Yonkers gneiss. The foliate texture is prominent and has a north-south strike with a vertical dip. The joint structures include a horizontal set spaced about 8 feet, along which the stone is quarried in benches. There are also north-south and east-west sets spaced about 20 feet apart. On the north side of the quarry, the east-west joints are more crowded, practically forming a heading, and the rock in that section is adapted only for road material.

The quarry is worked in a small way and the stone mostly sold dressed as lintels, sills etc. Hand drills are used and the stone broken out by black powder. The only mechanical equipment is a horse derrick. Some good-sized blocks are quarried, the largest measuring about 3 by 6 by 8 feet. The rock breaks quite smoothly along the foliation.

Russo quarry

A small quarry has been opened in the last few years and recently operated by John Russo. It lies about 1000 feet south of the Hackett quarry on Midland avenue, near Dunwoodie. The rock is the same fine-grained bluish or pinkish gneiss, of foliate structure, but is rather more broken than at the former quarry. The vertical and horizontal joints are mostly spaced at intervals of 2 or 3 feet, so that large-sized blocks are seldom quarried. The product is building stone, employed locally in the construction of dwelling houses. The scrap and inferior quality rock are sold for road material. The work is all done by hand.

A microscopic examination of the gneiss from this quarry shows that there is considerable hornblende in addition to biotite, which is the prevailing dark mineral. The feldspars and quartz are partially granulated and the uncrushed remnant is drawn out along the planes of foliation, the larger and smaller particles often occurring in alternating bands. The rock is quite fresh, except for the incipient alteration of the biotite. This has set free some iron which as limonite forms a slight stain along the cracks and sutures. Zircon and titanite are fairly abundant accessory minerals. The average diameter of the quartz and feldspar particles is between .5 and 1 mm, so that the texture is unusually fine.

Beekman quarry

The Beekman quarry is perhaps the oldest of the quarries in the Yonkers gneiss. It was worked in the early part of the last century and has been operative at intervals down to the present. It is situated at Phillipse Manor, about a mile north of Tarrytown, and is thus outside the principal areas of Yonkers. The principal opening reveals a bluish gneiss which is much fractured and intersected by a pegmatite dike. The latter occupies nearly one-third of the face which measures 60 feet in width. The gneiss strikes north and south and dips 60° east. When visited in 1911, the quarry was equipped with one steam drill and a rock breaker. In recent years the output has been used on the estate of which the quarry is a part for road and foundation work.

South of the main cut is an opening in a bluish and pink variety of gneiss. The blue is much jointed, while the pink gneiss appears to be very brittle.

The Beekman quarry has supplied material for several structures in Tarrytown, including churches and other buildings.

Kensico quarries

The principal quarry development of recent date in the Yonkers gneiss is that of H. S. Kerbaugh, Inc., the contractor on the new Kensico reservoir which is to form a part of the Catskill water supply system. To increase the capacity of the reservoir, a dam that will be 100 feet higher than the old structure and of correspondingly massive proportions is in course of erection at Valhalla at the south end of the reservoir. This structure is to consist of Yonkers gneiss obtained from an area explored to the east of the ridge, about one-half mile northeast of the dam.

The geological features of the reservoir site have been presented by Berkey,[1] who also investigated the various quarry materials of the vicinity with the view to their adaptability for use in the work. The Yonkers gneiss is an outlier of the main belt and is exposed on the ridge to the east of the reservoir, while the west side is made up of Manhattan schist, with Inwood limestone in concealed outcrop between the two.

Berkey mentions several quarries in the vicinity that have not been previously noted. These include the Outlet quarry, 1500 feet east of the northern extremity of the old reservoir; the Ferris quarry 1000 feet farther north; and the Dinnan quarry 3000 feet north of the Outlet quarry. All these are in Yonkers gneiss or massive phases of that rock. In addition he mentions the Garden quarry, about midway of the reservoir and 500 feet east of its margin, opened in dioritic gneiss; the Smith quarry, less than 1000

[1] Geology of the New York City (Catskill) Aqueduct. N. Y. State Museum Bul. 146, 1911, p. 191–200.

feet east of the southern end of the reservoir, in a mixture of igneous and Fordham gneisses; and the City quarry, on the eastern margin of the reservoir, also in a mixed phase.

The quarries from which the supply of stone for the dam is being obtained are apparently a new location, considerably south of the others in the Yonkers area. They are based on an exposure of several acres, thinly covered with soil which, when removed, shows glaciated but practically fresh rock at the surface. The first few inches from the surfaces show a slight brownish stain, but no marked decomposition. There are scattered inclusions of micaceous and hornblendic gneisses, the former perhaps derived from the Fordham. For the most part, however, the area consists of Yonkers in quite uniform development, well suited for architectural or general construction purposes. There is some variation of texture which ranges from massive and medium or coarse-grained to finely granular foliated gneiss. The massive type appears in limited quantity. The foliation is in part a result of flowage when the mass was still in a viscous condition. Pegmatitic and aplitic phases of the rock are not infrequent, the two occurring in irregular patches rather than dikes. The pegmatite is distinguished by large red, perthitic feldspars and smoky quartz with more or less graphic intergrowth of the minerals.

The jointing is widely spaced, as a rule, and no difficulty is found in obtaining blocks of any required size. The stone is quarried by drilling and blasting. The rough blocks are used for cyclopean masonry or are dressed to dimensions, while the finer material goes to the crushing plant which has been erected near the quarries. In the spring of 1913, work was in progress at two places.

The average product of the quarries may be described as a grayish or brownish gray gneiss of medium to fine texture. The feldspars range from .5 mm to .3 mm in diameter. The composition is that of a normal biotite granite, with microcline as the chief alkali feldspar. The feldspar and quartz are in nearly equidimensional grains, closely crowded, but not interpenetrating, as in some of the stronger granites. The even granular type seems to break down more readily under the weather than the irregular grained Yonkers, but at this place there is little evidence of physical disintegration.

Physical tests. The Yonkers gneiss from the Dinnan quarry, of probably similar character to the stone in the new quarries, was tested by J. L. Davis, of the New York City Board of Water Supply. Two samples showed: specific gravity 2.64; ratio of absorption .30 per cent and .39 per cent; porosity .87 per cent and 1.01

per cent; weight for each cubic foot 163.3 and 161 pounds; percentage of water absorbed .30. The ratio of absorption and porosity are considerably higher than the figures obtained on the Yonkers gneiss of the Hackett quarries, which are given elsewhere.

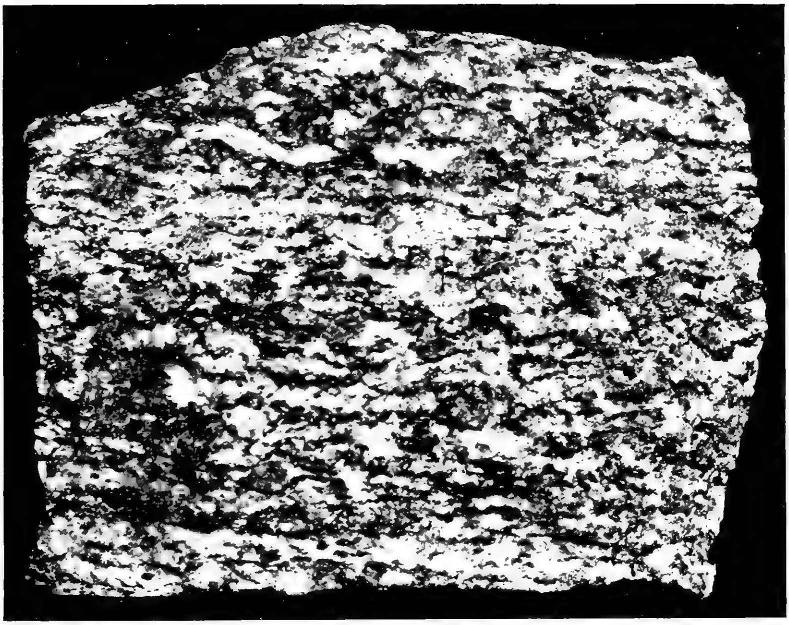
THE HARRISON DIORITE

The Harrison diorite covers an area of several square miles within the towns of Mamaroneck, Rye and Harrison, Westchester county. It forms two nearly parallel belts striking northeast and southwest, of which the easterly one extends along the sound from Port Chester to Milton Point and the westerly one, 2 or 3 miles inland, from the Connecticut line to near Larchmont station. The belts are only about a mile wide at most and show intrusive contacts with the Manhattan schist. Across the Connecticut border, they unite with a large area of the same rock that is known there as the Danbury granodiorite.

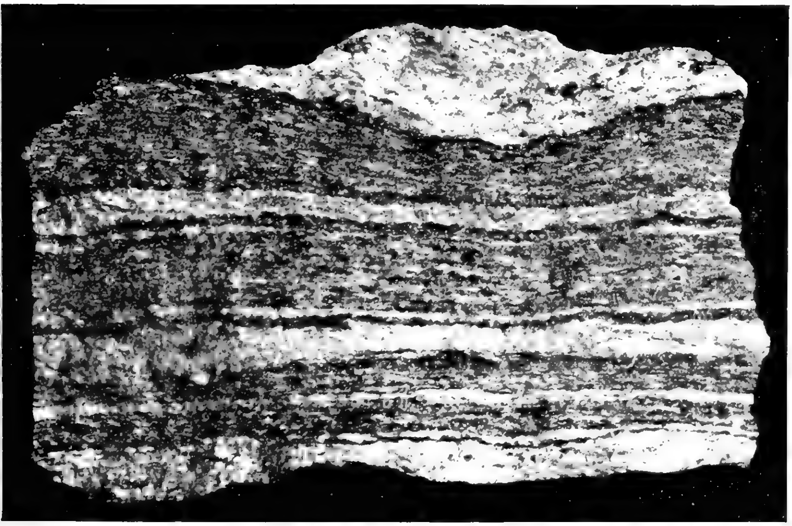
The rock has a well-marked gneissoid texture, which indicates that it was intruded before the igneous and sedimentary formations of this section were metamorphosed. The date of the intrusion, therefore, is earlier than the period of folding that came at the close of the Paleozoic and later than the Manhattan schist. The diorite resembles in composition the more acid members of the Cortlandt series, but its foliation indicates a separate and prior period of formation, for the Cortlandt rocks are practically unchanged.

Strictly speaking, the rock is a granodiorite, as in its general development, it shows affinity with the granites through the presence of quartz, and considerable alkali-feldspar. The quartz is in fine grains and has a smoky color. The feldspar includes a white plagioclase of andesine to labradorite composition and a nearly colorless microcline. Besides the fine granular feldspar of the groundmass, there are quite frequently porphyritic individuals which have been compressed into lenses or *augen*. These are made up of twin crystals. They measure up to an inch or so long and half that in width, but are more commonly of smaller dimensions. The longer axis and the twinning planes are parallel to the rock foliation. Biotite is the chief ferro-magnesian constituent, but is supplemented by a little hornblende. The biotite is plentiful, in scaly aggregates that interleave the quartz and feldspar. Parallel to the foliation thus produced, the rock breaks more or less readily and the resulting surface is always much darker than the fractures across the foliation. Of smaller importance is garnet which appears in

Plate 21



Harrison diorite, characteristic foliated structure. Quarry Mamaroneck.



Fordham gneiss, banded by lighter granitic material. Dublin quarry, Westchester county.

reddish grains, of irregular form, scattered through the groundmass; the grains are not conspicuous as they are seldom over 5 mm in diameter.

The color of the diorite is dark gray, with a bluish tint. The hammered surface, which is the usual finish, shows lighter and is quite attractive.

Faillace quarry

The quarry operated by Faillace Brothers, of Mamaroneck, is on the north side of the New Haven Railroad, and a little west of the village. It is in the western of the two parallel belts. In the spring of 1912, it was the only active quarry in the diorite.

The quarry is situated on the side of a low ridge, which has a northeasterly trend parallel to the general strike of the country rocks. The face is about 200 feet long, falling to 30 feet at either end. There is no sheet structure, but a system of discontinuous joints, 6 or 8 feet apart, dips at a low angle to the south, parallel to the surface. The principal jointing strikes and dips with the foliation, that is, strikes northeast and dips northwest at an angle of 65°. There are also cross-fractures, but they maintain no regularity.

The rock is a dark, very biotitic variety of the diorite, but rather more uniform in appearance than the average rock, and fairly free of knots or streaks of any kind. It carries porphyritic feldspars, which are usually compressed into lenses, or completely granulated, and which may reach an inch in maximum diameter. The uncrushed individuals show simple twinning after the Carlsbad law. The body of the rock has a fine grain, the quartz and feldspar averaging about 2.5 mm across. Pink garnet is usually present in small scattered granular aggregates that are noticeable but not conspicuous. The rock has a fresh appearance which is confirmed by negative tests for carbonates with dilute hydrochloric acid.

The quarry is equipped with two derricks. There is a crusher for using the waste. The principal product is rough and dressed blocks for building purposes, foundations, walls etc. The dressed material, for the most part, is finished with the patent-hammer. The stone is well suited for practically all purposes that do not require a light color or a fine finish. It is not susceptible, of course, to polishing. The waste is sold for riprap or crushed at the quarries.

Campbell quarry

The Campbell quarry, which is the only one in the vicinity mentioned by Eckel, has not been worked in the last four years. It is situated along the highway, just north of Larchmont station. As the vicinity is now a residential section, it is doubtful if work will again be started.

The diorite is here massive or slightly foliated, and of lighter color than the average. It shows effects of weathering in iron discoloration and clouding of feldspars. Pegmatitic segregations of the constituents are noticeable in places. The foliation strikes northeast and dips about 55° northwest, conforming to which is the principal joint system.

The product of the quarry is stated to have been about 1000 cubic yards a year, mostly dressed stone.

A quarry, owner unknown, is situated in the interval between the Campbell and Faillace quarries, southwest of Mamaroneck. It was not in operation in the spring of 1913, and apparently had been abandoned for several years. It shows a face 100 feet long on the strike of the diorite and from 20 to 35 feet high, with a width of 50 feet. The structural features resemble those at the Faillace quarry. The rock is a dark gneissoid type, quite uniform as to composition and appearance. Pegmatite in small segregations and stringers is the only variation at all noticeable. There is no equipment on the property. The product seems to have been mainly dimension stone.

THE FORDHAM BANDED GNEISS

The Fordham gneiss is a variable rock, or rather an assemblage of more or less contrasting types, which spread over an extensive area on the east side of the Hudson. It occurs in several belts that follow the general northeasterly structural trend and that have the Harlem river as their approximate southern boundary. In southern Westchester county, it borders the Yonkers on both sides, and a small strip continues along the eastern edge of the main Yonkers area to its northern end. Another belt is exposed along the Hudson from the Harlem river northward, occupying most of the first line of ridges that parallel the river.

The Fordham is a banded gneiss, in which respect it differs from the Yonkers. This banding is caused by variation in mineral composition, the lighter bands having less biotite than the darker ones. Some light bands are made up of nearly pure quartz, but usually there is a large proportion of feldspar. In the main, the rock may be classified as a biotite gneiss, composed of quartz, feldspar and biotite in fluctuating amounts. The feldspars are orthoclase, microcline and an acid plagioclase, the latter having the characteristics usually of oligoclase. The color is grayish and averages darker than the Yonkers, owing to the larger proportion of biotite. The texture inclines to finely granular, except when injected by coarse granite.

With respect to the other gneisses and igneous rocks of this section, the Fordham occupies a basal position, so that its early Precambric age seems established. It is clearly intruded by the Yonkers. As it is made up largely of sedimentary material, it may be classed as Grenville, which is the position assigned to it by Berkey.

The sedimentary derivation of the gneiss is strongly suggested by the regularity and persistence of the banded structure, which resembles true stratification. Further evidence of this origin is found in the gradation into quartzite that is observable in places, and also by the bands, streaks and irregular masses of calcareous material which are included within the formation. These inclusions become of considerable importance in the northern extent of the Fordham and are seen not infrequently in Westchester county. The banding of the gneiss is referable in greater part to variations in the original sediments which are believed to have been of the nature of impure limestones, shales and shaly sandstones.

Granitic and pegmatitic injections have taken place in parts of the Fordham along the planes of foliation. The igneous material may form thin bands or veins that alternate more or less regularly with the gneiss, with sharp contacts; or it may impregnate the body of the gneiss itself. Occasional dikes of these rocks cut across the bedding.

Physical character and composition. The gneiss is medium to dark gray in color, with a pinkish tone when there is much granitic mixture. The banding is its most striking feature. By reason of the parallel arrangement of the biotite, the dark bands partake of a certain degree of schistosity, cleaving or breaking rather readily along the foliation. The most persistent joints follow the foliation. These are variably spaced, from a few inches apart, where the gneiss has been crumpled or shattered, to several feet in the uncontorted rock.

The texture of the gneiss is fairly even but extremely fine. The diameter of the feldspar particles ranges from .25 to 3 mm, and the quartz is only slightly larger. The feldspar in most places shows incipient kaolinization, but otherwise there is little alteration noticeable. The biotite is somewhat bleached and the iron set free is segregated in the cracks and sutures. Muscovite and hornblende are usually present in small amounts.

An average sample of Fordham gneiss taken from the Nichols quarry, showed a specific gravity of 2.66. The ratio of absorption was .165 per cent and pore space .438 per cent.

Quarry development. There are only a few active quarries in the Fordham belts. The variability and foliated structure of the gneiss operate against its extended use as building material. Still the Dublin and Hastings quarries have furnished considerable building stone, selected from the coarsely jointed ledges, which has given good satisfaction so far as concerns durability. Its principal sale is in rough blocks for foundation work and crushed for concrete and roads. As a road material it is rather inferior, owing to its tendency to split in platy pieces.

There are quarry sites at Uniontown, Bryn Mawr, Lowerre and Fordham, from which no stone has been taken in recent years. The Uniontown quarry, according to Eckel, was worked for rough stone for one of the Warburton avenue bridges. It yielded a contorted gneiss inferior to that worked in the present quarries.

Near Bryn Mawr, two small openings in the Fordham are found on Palmer avenue, near Fort Field reservoir. The eastermost is stated by Eckel to yield a crumpled, poor grade of stone. The westerly opening shows a better quality which is exemplified in the walls and gatehouse of the reservoir. Some of the rock was crushed for macadam.

The Lowerre quarries were opened in 1898. The gneiss here shows granite veinings and is intersected by a pegmatite dike. Rough foundation stone has been the principal product.

The Fordham quarries were situated just south of that place and west of the Harlem railroad. They furnished crushed stone mostly, used for railroad ballast. Their sites are now occupied by buildings.

Reilly quarry

The Reilly quarry, owned and for many years operated by Patrick Reilly, is one of the more prominent ones for the production of building stone. It is situated at Dublin, southwest of Tarrytown, about 1½ miles east of the river. For the last three years the property has been leased to Thomas Murphy of Irvington.

The rock at this place is a hard, banded gray gneiss with a considerable proportion of igneous material. Seams and bunches of granite and pegmatite are common. The foliation and banding strike N. 30° E. and dip 80° southeast. The bedding joints are rather widely spaced, so that thick blocks are obtainable. A horizontal system of joints is present. The quarry was formerly worked in two faces, one 30 feet and the other 50 feet high, but of late years the stone has been taken out without much method. The opening is about 200 feet long and has been extended about an equal distance back from the highway. The stone is hauled to Irvington, a distance of 2 miles, for shipment. It is chiefly sold on contract, so that operations are somewhat irregular.

The principal structures in which the stone from this quarry has entered are the Rockefeller and Archbold residences at Tarrytown.

Duell & Holloway quarry

The firm of Duell & Holloway, of Tarrytown, owns a quarry near Glenville, 2 miles southeast of the former town, which appears to be situated in the Fordham gneiss. The rock is fine grained, grayish and irregularly banded. The darker seams contain abundant biotite and hornblende, the latter more prominent than is usual with this gneiss. The texture is firmly knit, almost like that of granite, and the stone is hard and tough. It shows no marked tendency to split into tabular blocks, as in fact the foliation, so marked in the average Fordham, is quite obscure in the hand specimens from this quarry. The feldspars which are mainly under 2.5 mm diameter, belong mostly to orthoclase and oligoclase, the former cloudy and micasized, and the latter less altered, but showing effects of compression.

The banded structure and foliation strike N. 50° E. and dip about 30° southeast. A system of nearly vertical joints is very closely spaced so as to make the product more suitable for crushing than for building purposes. The horizontal set of joints is less in evidence. Granite seams occur irregularly parallel to the foliation.

The quarry opening extends about 900 feet in the longer direction. There is little method apparent in the operations, as the principal object has been to break down the stone at the least possible expense without reference to the production of dimension material. The output is employed mainly for crushed stone which is sold in the vicinity.

Nichols quarry

The Nichols quarry, situated southeast of Hastings, on the road to Unionville, is a continuation of the old Lefurgy's quarry which at the time of Eckel's report was one of the principal quarries in the Fordham gneiss. The quarry is worked by W. H. Nichols, of Hastings. The opening extends about 300 feet on the strike of the gneiss, which is nearly north and south; it is about 100 feet wide and the face on the west side about 30 feet. The quality of the rock exposed in the quarry is somewhat variable. The best quality is found in the west side where a massive gray gneiss is quarried for building stone, in blocks that measure up to 10 feet long and 4 to 6 feet in section. Through the middle of the quarry runs a band about 18 feet wide of a darker, seamed, or contorted gneiss. There is more or less granitic admixture with the gneiss, but this is not usually injurious to the strength or appearance of the stone.

Besides the bedding joints that run with the foliation and dip 80° east, there are two well-developed sets at right angles to the foliation, the one dipping 80° south and the other 35° north.

Microscopic examination of the gneiss from this quarry shows the mineral composition to be like that described for the typical Fordham. The texture is even grained for the most part, and very fine, with indistinct banding. The feldspar and quartz particles average under 1.5 mm and the biotite scales are of about the same diameter. There is only an occasional shred of hornblende. Among the accessory constituents is zoisite in small rounded grains. Sulphides are absent. The only mark of alteration is a slight clouding of the feldspar, due to incipient kaolinization. The specimens showed no effervescence with muriatic acid.

A hand derrick and steam drill comprise the quarry equipment. The blocks are loosened from the ledge by drilling deep holes and loading with black powder, after which they are broken up by hand drilling. The stone is sold rough and dressed for building and foundation work. The waste is sold as crushed stone for macadam.

Fenano quarry

A quarry in Tuckahoe has been operated for several years past by Nicholas Fenano. The rock is a compact bluish or grayish gneiss of the Fordham type, but somewhat contorted and broken by numerous joints. The opening is about 200 feet long on the strike of the gneiss and shows a face of 40 feet. The strike of the beds is north and south and the dip vertical. Most of the product has been sold as crushed stone, the larger blocks only being utilized for foundation or building work. The ledge has been worked nearly down to the street level and it is probable that the quarry will soon be converted to other use.

THE MANHATTAN SCHIST

The Manhattan schist which underlies the island of Manhattan and extends northward into the Bronx and Westchester county has no great importance as a quarry stone. Its foliation, variable composition and thinly jointed character are against its general use for architectural purposes or for cut stone, though it has been employed quite extensively for walls and rough masonry where readily available. In a few places, specially in the vicinity of plutonic intrusives which have invaded and injected the schist, thereby rendering it more massive and compact, it has found some sale for building stone.

The schist, like the Fordham gneiss, is a metamorphosed sediment; in its original form probably a shale. In the field there is a close resemblance between the two, though stratigraphically they are separated by both the Lowerre quartzite and the Inwood limestone. A comparison of typical samples of the schist and gneiss shows, however, that the former is more micaceous and carries less of the feldspars than the Fordham. The mica in both is mostly biotite, but in the Manhattan schist there is also considerable muscovite. The feldspathic constituents are generally subordinate to the quartz.

The color of the Manhattan schist is gray, medium to dark, the lightest being the injected phases. Foliation is marked, owing to the abundance of mica, and follows apparently the original stratification. Crumpled and thin-jointed types are common.

The schist is intruded by dikes and small bosses of granite and occasionally of diorite and more basic rocks. In their vicinity, but especially near the granitic intrusives, it is likely to change considerably in appearance and composition. Through the injection by granite, it develops into a feldspathic rock which resembles a banded gneiss or, when the schist is more thoroughly absorbed, it becomes fairly uniform and quite massive, not unlike the granite itself. Such mixed phases are too numerous to require separate mention. Merrill has noted their occurrence also in connection with the diorite intrusions north and east of New Rochelle.

Besides mica, quartz and feldspar, the schist contains a number of accessory minerals like garnet, sillimanite, titanite and magnetite. The texture is generally fine, even granular, but may become porphyritic near igneous contacts through the development of large feldspars. The rock possesses no features that are objectionable to its general employment for construction purposes, except its somewhat variable appearance and foliation. The mica which is in the scales arranged parallel to the foliation makes it readily cleavable and is a source of weakness if proper care is not used in laying the stone. It should not be placed, of course, on edge, as the effects of water and frost are greatly accentuated if the foliation is thus exposed.

There are no permanent quarries in the Manhattan schist. Most use of this stone has been made in foundation and retaining walls on Manhattan island and much of the material has been taken from excavations on building sites. The local operations, therefore, do not call for special mention.

GRANITE NEAR RAMAPO, ROCKLAND COUNTY

The belt of Precambric gneisses which enters southwestern Rockland county from New Jersey, forming the massive ridges of the Ramapo mountains, contains several quarries around Suffern and Ramapo which have supplied building stone for local uses and to some extent for shipment. The gneisses are pink or gray and carry hornblende or biotite as the iron-magnesia mineral. In general composition they resemble granite, being composed mainly of acid feldspar and quartz. They range from foliate, thinly bedded types to heavily jointed massive examples. The latter, of course, are better adapted for all constructional work, in which they take the place of true granite. They are intersected by vertical joints of which there is usually a system running nearly north-south and a second at about right angles.

The quarry sites are situated along the Erie Railroad between Suffern and Ramapo. One of the principal openings, but idle for many years, lies on the ridge south of Ramapo and west of the railroad tracks. The rock is a hornblende gneiss of massive character, reddish in color. Smock mentions the quarry as having furnished building and monumental stone, as well as material for many of the Erie Railroad bridges.

A quarry near Hillburn was worked by Rice Brothers up to the year 1904. The output consisted of building, monumental and rough stone.

GRANITE AND GNEISS IN ORANGE COUNTY

Several granite intrusions are found in the southwestern part of Orange county, near the New Jersey state line. Two of these constitute rather large bosses that rise into the conspicuous twin peaks Mounts Adam and Eve, at the edge of the " Drowned Lands " of the Wallkill river. Both are made up of a coarse hornblende granite, somewhat gneissoid in places and showing pegmatitic and aplitic variations. Mount Eve, the larger boss, occupies an area about 2 miles long and a mile wide. Mount Adam is a nearly round mass, about one-half of a mile in diameter. There are small knobs of the same granite near Big island, just northeast of Mount Eve and also in the section southwest, along the general axis of the main intrusion.

Pochuck mountain, a broad ridge which lies principally in New Jersey, consists of Precambric gneiss broken here and there by granite. On the northeastern end, the part within New York State, the easterly slopes are formed by a coarse, quite massive, hornblende granite, but the western half is made up of biotite gneiss. The granite is lighter in color than that just mentioned but its mineral composition is similar and it may be of related origin.

The section of the Highlands in the vicinity of these intrusions possesses much interest to the geologist. The contact zones between the granites and the bordering limestones are especially notable and have long been a favorite collecting ground from which much material has found its way into museums. The geological features of this section are set forth in numerous papers and reports, the more recent being those by Kemp and Hollick [1] and by Ries.[2]

Quarries on Mount Adam and Mount Eve

Practically the same kind of granite is exposed on the two knobs, Mount Adam and Mount Eve, and they belong no doubt to a single intrusion, though separated by a belt of crystalline limestone. Mount Eve, the larger knob, rises to an altitude of 1057 feet above sea level; its greatest axis in the direction northeast-southwest is about 2 miles. Mount Adam, which is really a spur on its western flank, measures little more than one-half of a mile in diameter, with a summit about 100 feet below that of Mount Eve. Smaller knobs of the granite are found at Big island, just north of Mount Eve and on the eastern and southern borders of the mountain.

The granite resembles that from Pochuck mountain in general character and composition. It belongs to the hornblende granites,

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[1] The Granite at Mounts Adam and Eve and Its Contact Phenomena, N. Y. Acad. Sci. Annals VII, 638.

[2] Report on the Geology of Orange County, N. Y. State Museum Rep't 49, 2, 1895.

but contains some biotite. It has a coarse texture, as seen at the quarries, and in color is a medium gray with bluish or greenish tints which arise from the variable appearance of the feldspar crystals. These measure from 5 to 15 mm in diameter. Though generally massive, the granite shows local phases characterized by a parallel or gneissic arrangement of the constituents, as is well exhibited on the north side of Mount Eve. Pegmatitic variations are rather frequent, especially on Mount Adam, where also the normal, coarse, grayish granite gives way in places to a finer grained and much darker dioritic rock. This lack of uniformity constitutes a serious drawback to the opening of quarries in many parts of the exposures.

The quarry localities are on the north slope of Mount Adam and the western slope of Mount Eve. The Mount Adam quarry, according to Smock, was opened in 1889 by the Mount Adam Granite Co. of Middletown. It has long since been abandoned. The workings have a total length of 250 feet and a face from 20 to 30 feet high. There are two grades of rock exposed, the one consisting of the usual coarse hornblende granite, and the other of finer grain with little hornblende, forming streaks and patches in the first. Feldspathic and pegmatitic seams are present. The jointing is divided into three systems. Two strike north-south and dip about 70° in opposite directions, the third strikes N. 45° E. and dips 55° southeast. No equipment is found on the property. The quarry lies about one-half of a mile north of the railroad to which the stone was formerly hauled over a private road.

The Mount Eve quarries were opened about 1890, at the same time as those on Pochuck mountain and by the same company. They are situated a little way up the western slope, in the notch between the two knobs. They have likewise been abandoned and the equipment removed from the property. The granite is less broken than on Mount Adam and shows more uniformity of character. It was worked quite extensively for dimension stone which was shipped to Orange, N. J., and other places. The workings at present are so heavily overgrown with bushes as scarcely to permit inspection. The nearest point of shipment on the railroad is about 1½ miles distant.

Microscopic characters. The petrography of the granite is described in detail in the paper by Kemp and Hollick, already cited, from which the following information is abstracted. The principal dark mineral is hornblende, but there is more or less biotite associated with it, as well as some pyroxene. The feldspars include orthoclase, microcline and microperthite among the alkali varieties. Plagioclase is represented in amount quite equal to the others, so that the composition approaches a diorite. The quartz carries abundant inclusions but otherwise is not especially remarkable. Less important constituents are titanite, zircon, magnetite and allanite, the last being quite common in the granite from both quarries.

Pochuck Mountain quarries

The principal quarry working in the Pochuck granite area is situated just north of the State boundary and on the east side of the mountain. It is reached by the branch railroad that connects Pine Island on the main line with Glenwood, N. J. It was opened about 1890. The property was developed and worked by the Empire State Granite Co., but has been inoperative for the last four or five years. Building stone and paving blocks were quarried. Among the structures in which the granite has been used are the post office and the Hinchcliffe brewery at Patterson, N. J.

The quarry is opened for a distance of 200 feet along the mountain and has a face from 30 to 40 feet high. The excavation is insufficient to show the general rock structures. There appears, however, to be no well-defined sheeting.

A second smaller quarry has been opened a little south of this property, but is also idle at present. It belongs to P. J. Carlin of New York City. The granite is of the same general character as that in the Empire State quarry.

The granite from this locality has a coarse texture, varying from massive to slightly foliate, and a pink body that is mottled with gray and black. The general color effect is pinkish gray of medium shade. The feldspars measure about 10 mm and the black aggregates of hornblende and biotite from 5 to 10 mm in diameter. The granite in hand specimen shows no weathering or discoloration.

Microscopic examination. The feldspars, which are the most prominent constituents, include microcline, microperthite and orthoclase of pink color and a whitish soda-lime variety, all in practically unaltered state though somewhat fractured by compression. Quartz is next in amount. The hornblende greatly predominates over biotite and is a strongly pleochroic, dark green to brown variety, showing slight chloritization. Large crystals of titanite are included in the dark aggregates of hornblende and biotite. Zircon, apatite, magnetite and biotite are present in small quantity. The absence of carbonates is indicated by hydrochloric acid tests.

Chemical analysis. The following analysis was reported by the Empire State Granite Co. in reply to a request from the State Museum dated in 1904. The analysis was made in the laboratories of Simonds & Wainwright of New York:

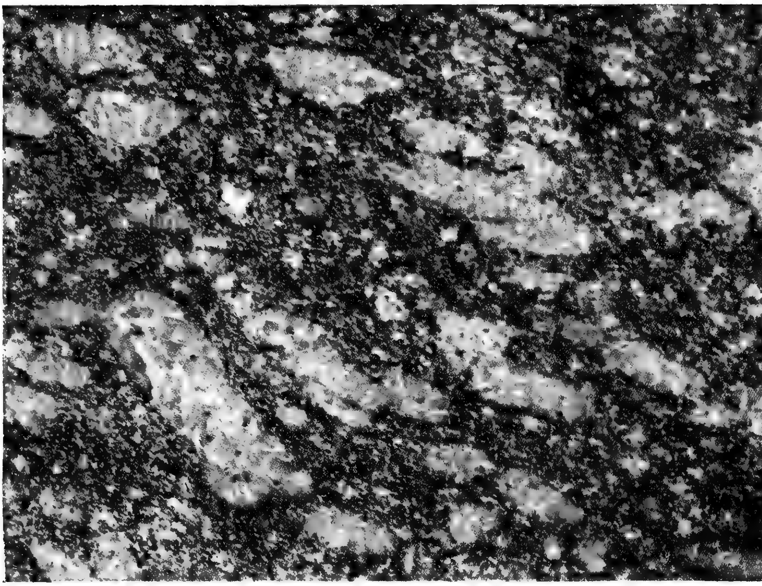
SiO_2	66.12
Al_2O_3	13.71
Fe_2O_3 } FeO	6.42
MgO	1.15
CaO	3.45
Na_2O	3.61
K_2O	4.31
H_2O	.87
S	.07
MnO	tr
	99.71

Physical tests. Compression tests of the granites from this quarry, made by Prof. P. J. Carlin, showed an ultimate strength of 23,500 pounds to the square inch in one sample and 22,900 pounds in a second sample. Gravity and absorption tests by the writer gave: Specific gravity, 2.74; ratio of absorption, .148 per cent; pore space .402 per cent.

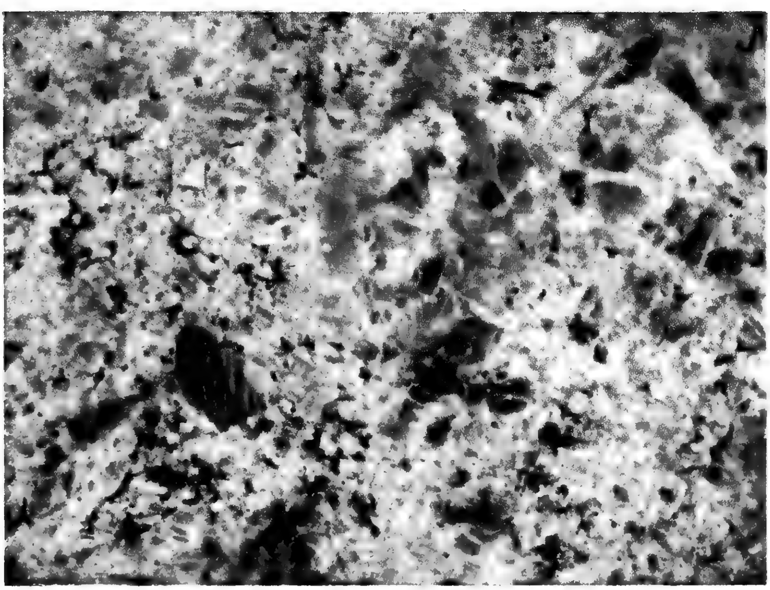
West Point gneiss quarries

The notable collection of buildings at West Point affords an example of the architectural use of local stone to good advantage, an example that might be profitably followed more frequently perhaps than is usual in this section, although there are not a few instances of the adaptation of native quarry materials to be found in the Highland region. The larger structures at West Point, including the new chapel, the power plant, riding hall and several others, are built of dark gray gneiss that is found on the side of the ridge to the west of the academy grounds. The quarries are worked only as the need develops from time to time, being used only to supply the local requirements. There are several openings, but the principal one from which building stone has been quarried of late years is near the north end of the ridge and somewhat above the main level of the academy site. The gneiss is quite fresh at the surface which shows the effects of glacial erosion in deep scorings and polished surfaces. It is a coarsely jointed biotite gneiss, veined and broken by a more massive granite. The two rocks vary much in proportion from place to place and there is every gradation between

Plate 22



Porphyritic granite. Horicon, Warren county



Pegmatitic granite. Orange county

the thinly foliate gneiss and the massive granite. Within the limits of one quarry, however, material is found that is fairly uniform. It fills all the requirements for rock faced ashlar, as it is strong, durable and quite attractive if somewhat somber of tone.

Pegmatitic granite in Orange county

Within the Precambric belt of Orange county, which includes most of the Highlands area west of the Hudson river, occur numerous outcrops of coarse, reddish granite of pegmatitic nature. This rock is differentiated from the surrounding gneisses that form the main mass of the Highlands by its coarser grain and also by its more massive appearance, never showing the well-developed parallel arrangement characteristic of the latter. The feldspars reach a diameter of an inch or even more when uncrushed, and are inclosed in a finer mixture of granular feldspar and quartz, so as to lend the aspect of a porphyritic rock. The feldspar in the groundmass is the result largely of the breaking down of the larger individuals under compression, the uncrushed remnants having a rounded or lenticular cross-section. The predominant variety is red microcline, but there is also more or less of white or greenish plagioclase. Of dark silicates the rock carries very little ordinarily. On the other hand, magnetite is a common ingredient, and epidote appears quite often as an alteration product. By reason of the varied colors imparted by the feldspar, magnetite and epidote the granite not infrequently possesses ornamental qualities which make it serviceable for decorative work and it has been employed locally for that purpose in fireplaces, mantels etc. Unfortunately it does not occur in large enough bodies to be quarried on a commercial scale.

The granite may be seen in the form of stringers, dikes and irregular bodies which intersect the gneiss and are probably offshoots of some magma that has penetrated the country rocks from below at a time when the metamorphism of the latter had been completed. The same magma is possibly represented in the bosses of granite outcropping on Mount Adam, Mount Eve and Pochuck mountain in southern Orange county. The magnetite mines are situated mainly in belts of gneiss that have been injected by the granite, and afford good specimens of the fresh material. At the Forest of Dean mine back of West Point a very attractive variety occurs in contact with the magnetite, and there is a large amount of it on the mine dump.

THE DARK COLORED, BASIC ROCKS

BASIC ROCKS IN THE ADIRONDACKS

Traps or diabase dikes occur in great numbers in the main Adirondack region, though they are very unequally distributed. They occur with greatest frequency in the eastern and northern parts, embraced in Essex, southwestern Clinton and southern Franklin counties. As they were intruded during the Precambric they are not found outside the area underlain by the crystalline formations — the gneisses, schists, crystalline limestones and plutonic igneous masses; but they may be looked for in any of the rocks just named.

The Precambric area of Essex and Clinton counties includes numerous examples of the dikes, so many that their separate occurrence has hardly seemed worthy of note in the geological reports dealing with this section. They are particularly in evidence in the vicinity of the iron mines at Hammondville, Mineville, Ausable Forks, Lyon Mountain and in the Saranac valley; but are probably no more frequent there than elsewhere in the same region; they are simply better exposed. The writer has noted more than a hundred such dikes in these districts. They all present very similar features of physical development, consisting typically of feldspar, pyroxene and magnetite with the peculiar diabase texture which arises from the inclusion of the pyroxene within the meshes formed by the interlacing feldspar laths. As a rule they are fairly fresh at the surface and give a metallic ring when struck with the hammer. They have the tabular form characteristic of fissure intrusions and are seldom more than a few feet thick though persistent on the line of strike. Their prevailing direction is from north to northeast in conformity with the main structural trend of the inclosing rocks. The trap is well suited for road material on account of its toughness and wearing qualities, but the occurrences so far discovered are scarcely of sufficient size to justify quarry work. Dikes over 15 feet thick are very rare and of those seen by the writer a thickness of 30 or 40 feet represents about the maximum. They have a steep dip, usually nearly vertical, so that their quarrying would be difficult and relatively expensive.

A more available material for local road building in the Adirondacks is found in the areas of gabbro and basic syenite. The latter, normally a feldspathic rock, develops in places into a very dark material with abundant iron-magnesia minerals and magnetite, which closely resembles and even grades into the gabbros. The latter are almost identical in mineral composition with the diabase trap. Like these they are very tough resistant rocks, but normally are coarser grained and consequently would not wear so evenly under abrasive conditions. The gabbros occur in dikes, larger than those in which the diabase is found, but more frequently they form rounded and irregular masses or stocks from a few hundred square feet to several acres and even miles in area. They are very common in Essex county within the Lake Champlain drainage area where their occurrence in part is well shown on the Elizabethtown-Port Henry geologic sheet.[1]

The texture of the gabbros and syenites varies from coarse to fine, the finer sorts being on the borders of the areas, where the magmas were subject to quick chill. In these border places are to be found the most suitable material for crushed stone. Some of the gabbros exhibit textures very similar to the trap, their feldspar being in lath-shaped crystals which form a network that incloses the pyroxene in the meshes. Such border phases are practically equivalent to the diabases and should prove equally serviceable as materials for crushed stone of the best quality.

Numerous chemical analyses of the Adirondack traps, gabbros and syenites have been published in the geologic reports of this region.[2]

LITTLE FALLS, HERKIMER COUNTY

An outlier of the Adirondack crystalline rocks occurs in the Mohawk valley at Little Falls where quarries for the supply of crushed stone and, to a smaller extent, of building material have been operated for many years. The situation is very advantageous for extraction and marketing of stone as the area is crossed by two main railroad lines and the Erie canal, and there are bare rock ledges close at hand which afford good quarry sites. The rocks are principally adapted for road, concrete and foundation work, being rather dark for use in buildings. They include a fine-grained syenite which occupies most of the area, reddish granite and trap, the last occurring in a dike over 100 feet wide — the largest known in the southern Adirondacks.

The Little Falls outlier has been mapped and described by H. P. Cushing in connection with his report on the "Geology of the Little Falls Quadrangle" (N. Y. State Museum Bulletin 77). It consists of a single area of these Precambric crystallines that outcrops within

[1] Included in N. Y. State Mus. Bul. 138.

[2] See especially Museum bulletins 95 and 138.

the gorge of the Mohawk at that place and extends eastward for nearly 2 miles; the syenite forms the first lines of cliffs on either side, rising to a maximum of about 200 feet above the river, above which is a second steep scarp consisting of the exposed edges of Ordovician limestones whose base rests unconformably upon the crystallines.

The Little Falls syenite has a dark green to nearly black color, changing to yellowish or brownish on weathered surfaces. The texture is mostly fine granular, the result of mashing after intrusion. There are occasional feldspar "augen" in the midst of the comminuted minerals which may be taken as evidence that it once possessed a much coarser grain. Over much of the area it has a mashed gneissoid appearance and is thinly jointed, the joints causing a platy structure in places like that of a schist. There has been some infiltration of iron oxides along the joints and locally these extend into the body of the rock, filling the minute cracks and pore spaces and changing the color to a brick red.

In composition, the rock varies considerably from place to place and in many samples of the outcropping portion shows a wide departure from the syenitic type. In the eastern section, the mass develops very dark basic phases which are close to gabbro in mineral composition and in the hand specimen much resemble a fine-grained gabbro. Such phases occur along the tracks of the Dolgeville railroad, near the quarries of the Syenite Trap Rock Co. The feldspar constituents, however, belong to the alkali varieties, with subordinate amounts of lime-soda feldspar of andesine or oligoclase type, so that the material can not be classed as gabbro. Quartz is also present, as it is elsewhere in considerable abundance. The dark minerals include hornblende, hypersthene, biotite and garnet. Among minor ingredients are apatite, quartz, titanite, magnetite and pyrite. In the more acid phases, there is about 75 per cent of feldspar, chiefly microperthite, about 10 per cent of quartz and between 10 and 15 per cent of the iron-magnesia minerals. The basic examples carry as much as 50 per cent of the latter ingredients.

Throughout the exposure occur scattered patches and bodies of a reddish granitic rock, some of which seem to be in the nature of inclusions, rather than dikes. Such are found in the north face of the Trap Rock Company's quarry. Cushing regards the red granite found in the western section around Little Falls as intrusive in the syenite.

Chemical analysis. The following is an analysis of the Little Falls syenite extracted from N. Y. State Museum Bulletin 115, the analyst being E. W. Morley:

SiO_2	66.72
Al_2O_3	16.15
Fe_2O_3	1.23
FeO	2.19
MgO	.73
CaO	2.30
Na_2O	4.36
K_2O	5.66
H_2O	.77
MnO	.07
	100.18

The analysis is undoubtedly based on samples of the more quartzose rock.

Physical tests. Numerous tests of the Little Falls syenite have been made by the bureau of research, State Department of Highways. The following table gives the maximum and minimum and average results of eleven different tests:

	Maximum	Minimum	Average
Specific gravity	2.93	2.75	2.80
Weight pounds for each cubic foot	183	172	175
Absorption, pounds for each cubic foot	.21	.09	.15
Per cent of wear	4	2.6	3.3
Hardness	18.4	17.8	18.1
Toughness	14	8.5	11.7

Diabase dike. The dike that has been mentioned as intersecting the syenite is found in a slight depression of the surface about 1000 feet west of the Syenite Trap Rock quarry. It shows also in the face of the cliffs above the Dolgeville railroad cut and can be traced thence northeasterly toward the Little Falls road, but is concealed near the road itself if it reaches that far. The dike has been intruded along the course of the main jointing which here is N. 30° E.; the map in Cushing's bulletin, however, indicates the strike as nearly east and west. Within the exposed section, it measures about 125 feet in width, which may be taken as about the actual thickness. It thus could be quarried without difficulty. It ranges from very fine, even, glassy texture near the contact to a rather coarse grain with porphyritic feldspars an inch or so long in the interior of the body. Though somewhat altered in the outcrop, pieces give a metallic ring when struck, like a hard trap. Its mineral composition may be described as consisting of plagioclase, augite and magnetite, with secondary serpentine and chlorite.

Syenite Trap Rock Company's quarry

The Syenite Trap Company's quarry is situated 1½ miles east of Little Falls on the north side of the river and New York Central tracks. It was opened about ten years ago on an extensive scale for the purpose of supplying crushed stone for highway, canal and railroad construction. The present quarry cut is nearly 1500 feet long with a face of about 60 feet as a maximum. The stone is quite massive in appearance and is less broken by joints than in most of the exposure. It is extremely tough and resistant in the quarry, showing qualities that fit it for heavy service. The crushing plant is built on the side of the cliffs, the stone passing through the successive crushers and screens by gravity into the storage bin from which it can be loaded directly into cars. The plant has a capacity of from 800 to 1000 tons a day.

An interesting feature, though of some inconvenience to quarry operations, is the presence of numerous pot holes, both on top and side of the syenite cliffs, which attain a diameter of 30 or 40 feet in some instances. They are filled with transported boulders and pebbles of various rocks, many beautifully rounded and polished. They occur up to 200 feet nearly above the bed of the present river. A pot hole about 70 feet in diameter was encountered in the excavation for the new locks at Little Falls.

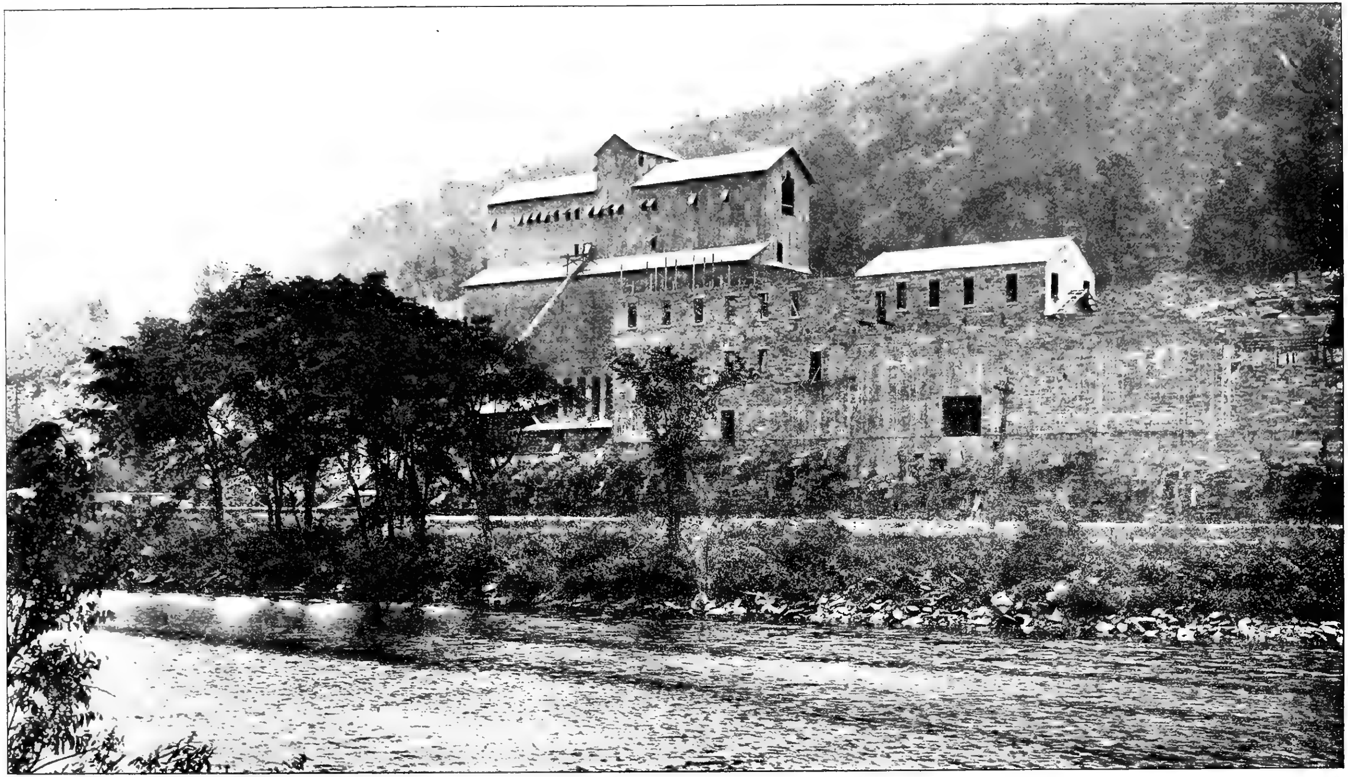
Little Falls Stone Company's quarry

The site of the Little Falls Stone Company's quarry is on the south side of the Mohawk, opposite the quarries just described. The syenite is exposed as a ledge for a distance of 800 feet in an east-west direction, with a face about 50 feet high in the center, sloping off somewhat toward either end. The rock is rather variable in structure, ranging from a platy schistose type, badly broken up, to a massive, heavily jointed material that has no definite cleavage. The quarry was opened for the supply of crushed stone for cement blocks. A large plant was erected near the quarry for making blocks, but has not been operated for the last four years and the quarries also have been idle during that time.

GREENFIELD, SARATOGA COUNTY

The Saratoga Trap Rock Co. has a quarry in the town of Greenfield, 3 miles northwest of Saratoga Springs. The rock is a fine-grained diabase, occurring in a dike which strikes N. 20° E. and extends across the line of the Delaware and Hudson Railroad

Plate 23



Quarry and crushing plant of the Little Falls Stone Company. Quarry is partly hidden by the trees, but can be seen at extreme left.

(Adirondack branch). The dike is notable for its continuity along the strike, although its thickness is nowhere very great, being about 60 feet from wall to wall in the quarry opening. It can be traced northward beyond the railroad by occasional exposures for over one-half of a mile and finally branches into two or three smaller dikes. The section south of the railroad is fully as long. The dike stands nearly vertical and cuts through a garnetiferous schist. The openings are just south of the railroad and east of the north-south highway. An examination of the diabase under the microscope shows that the mineral constituents are pyroxene, feldspar and magnetite in the order of their importance. The minerals are somewhat decomposed by weathering, though in hand specimen the rock appears hard and has a metallic ring.

FORT ANN, WASHINGTON COUNTY

Several dikes of trap are found on the ridge east of the canal, near Fort Ann. They are of small size, though their occurrence so near shipping facilities has given them economic interest and led to active quarrying in one case. The Champlain Stone and Sand Co. operated a crushing plant for a short time about 1907. The dikes are the usual diabase, with pyroxene, feldspar and magnetite as the principal constituents. Specimens examined by the writer showed slight decomposition but not sufficient probably to affect materially the wearing quality of the stone for road uses.

THE CORTLANDT BASIC ROCKS

A great boss of igneous rocks, mainly of the dark basic kinds, is found in northern Westchester county, just south of Peekskill. It covers a large part of the town of Cortlandt, having an area of about 25 square miles, rounded in outline and extending along the Hudson river for some distance on its western border. The intrusion has been described at length by J. D. Dana and G. H. Williams. More recently G. Sherburne Rogers[1] has published a very detailed account of the geology and petrography of the rock series, with many chemical analyses and a map showing the distribution of the different types.

According to Rogers's investigations, the intrusives consist of a complex of rocks of which the largest element is the norites, but including also gabbro, pyroxenite, peridotite, hornblendite, dior-

[1] Geology of the Cortlandt Series and Its Emery Deposits. N. Y. Acad. Sci. Annals, v. xxi, 1911.

ite and syenite. The various rock types are the differentiated products of a basic magma which was intruded in late Paleozoic time. It is thought that the Mohegan granite may represent the acid extreme of the series, although occupying a rather isolated position to the northeast of the basic intrusives. At any rate the granite has the same relations to the surrounding formations which consist principally of Manhattan schist.

There are no active quarries within the area and the only mineral product now worked is emery, which is found in small lenses and pockets near the borders. The rocks are too heavy and dark in color for building stone. It would appear, however, from observations by the writer that there are numerous opportunities for the quarrying of road material of good quality. The fine-grained gabbros and norites particularly seem well adapted for the purpose, being closely knit, tough materials, very similar to diabase in their composition. The best ledges, however, are found in the interior at some distance from the railroad and the Hudson river. The rocks in places are quite heavily charged with pyritic minerals as indicated by their rapid weathering with the formation of a reddish clayey soil. The pyritic zones are probably localized and do not seriously affect the quality of the material as a whole.

Analyses of representative types of the Cortlandt gabbros and norites are given herewith. No. 1 is gabbro, southeast of Salt Hill, H. T. Vulte, analyst. No. 2 is norite, 1½ miles south of Peekskill, S. S. Rogers, analyst.

	1	2
SiO_2	54.72	51.49
Al_2O_3	17.79	20.72
Fe_2O_3	2.08	1.80
FeO	6.03	7.28
MgO	5.85	3.82
CaO	6.84	6.71
Na_2O	3.02	3.70
K_2O	3.01	2.14
H_2O+	......	.31
H_2O-	......	.10
CO_2	......	trace
TiO_2	......	2.26
P_2O_5	......	.15
S	......	.11
MnO	......	.13
	99.34	100.72

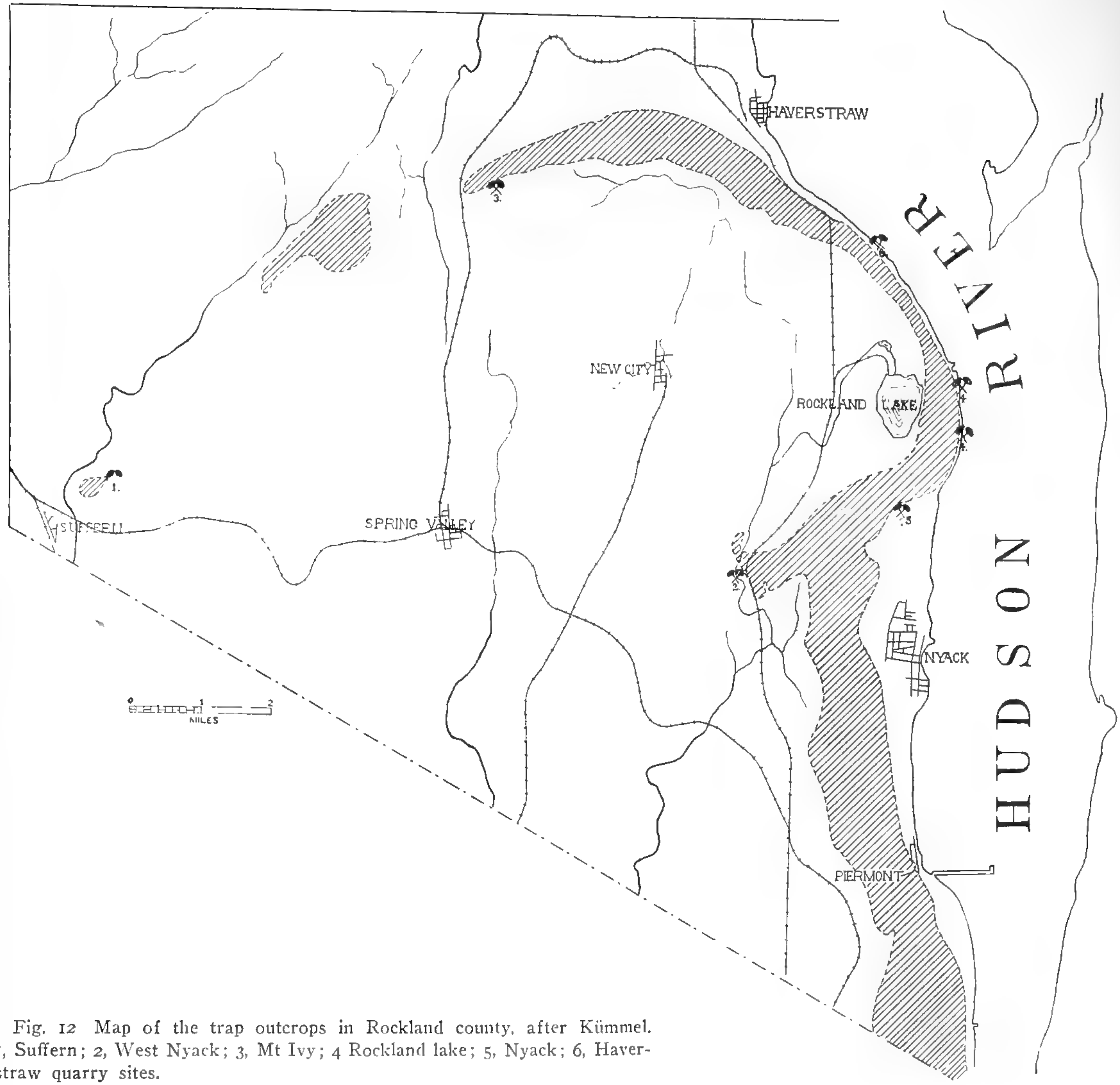


Fig. 12 Map of the trap outcrops in Rockland county, after Kümmel. 1, Suffern; 2, West Nyack; 3, Mt Ivy; 4 Rockland lake; 5, Nyack; 6, Haverstraw quarry sites.

PALISADES DIABASE, ROCKLAND COUNTY

The Palisades of the Hudson are the outcropping edge of an intrusion of diabase or trap, the largest anywhere in the State and, by reason of its accesible position, the most valuable for the production of crushed stone. The intrusion altogether is some 60 or 70 miles long north and south, and its width within the Rockland county section ranges from one-eighth of a mile to over 2 miles.

The diabase is in the form of a sheet which has ascended along the inclined beds of Triassic sandstone and shale. The dip of the beds is toward the west and northwest at an angle of from 5° to 15°. In this direction the diabase soon disappears and becomes buried under an increasing burden of sediments. The thickness of the sheet is several hundred feet at least and in places may be around 1000 feet. Although it follows in general the bedding of the stratified rocks, it is observed in places to cut diagonally across the beds for greater or less distances.

The trap exposure follows the shore line of the Hudson quite closely from the New Jersey state line to Haverstraw. Here the outcrop swings around to the west away from the river and after continuing in that direction for some 4 miles, thins out or disappears beneath the surface. In this part the sheet apparently cuts across the bedded rocks at nearly right angles to their strike. The exposure has been described and mapped very accurately by H. B. Kümmel.[1]

The diabase varies more or less in texture from place to place, but has a very uniform composition in which plagioclase, augite and magnetite are predominant and olivine, pyrite, quartz and other minerals are of minor importance. It is grayish to dark green in color, and shows very little alteration. The grain is moderately coarse, except near the upper and lower edges, where it is fine and compact.

For many years the diabase has been extensively quarried for crushed stone. It has also been worked to a limited extent for paving blocks and for building material, but the difficulty of cutting it has prevented any marked development of these uses. As a road metal it has long been recognized as the standard of quality. The quarries around Haverstraw, Rockland lake and Nyack in recent years have had an output annually of over 1,000,000 cubic yards of crushed stone.

[1] N. Y. State Museum Annual Rep't 52, v. 2, 1900.

Tests of the trap by the bureau of research, State Department of Highways, gave the following results on a number of samples:

	1	2	3	4	5	6	7	8
Specific gravity	2.96	2.97	2.88	2.81	2.92	2.96	2.98	2.82
Weight, pounds for each cubic foot	185	186	180	176	183	185	186	176
Water absorbed, pounds for each cubic foot	.68	.17	.40	.44	.26	.22	.23	.70
Per cent of wear	3.6	2.6	2.7	2.1	2.6	3.1	2.8	4.
Hardness	17.8	17.9	17.8	18.6	18.2	17.8	18.2	18.2
Toughness	14.5	17	16.5	22.5	17	16	22.5	14.5

In the near future the quarrying of trap from the face of the Palisades will probably be discontinued, as the river front is to be incorporated in the Palisades Interstate Park.

The property of the Manhattan Trap Rock Co., on the southeasterly face of Hook mountain, has already been taken over for purposes of the park and the crushing plant dismantled. The other quarries in this section are owned by the Rockland Lake Trap Co., the Clinton Point Stone Co. and the Haverstraw Crushed Stone Co. They are still operative (1914) but it is understood that negotiations for their purchase have been begun. With their acquisition the industry along the riverside, which is the most advantageously situated for the economic production and shipment of crushed trap will come to a definite end. The supply then must come from some of the inland quarries or from the New Jersey and Connecticut trap areas, in either case probably at an increase in cost.

The present quarries are well equipped and capable of turning out a large output at a low cost. The largest of them is owned by the Rockland Lake Trap Co., where there is a face of 2000 feet and 500 feet or more high. The rock is broken down in enormous quantity by drilling and blasting, loaded onto cars by steam shovels and crushed in the plants at the riverside whence it is loaded into barges for transport to New York and the other markets on the river and coast.

LADENTOWN, ROCKLAND COUNTY

Trap is exposed over a considerable area south of Ladentown and west of the branch railroad from Spring Valley to Haverstraw. The area is in line with the course of the Palisades intrusion from Haverstraw to Mount Ivy but is separated from the latter by a stretch of over a mile in which the rock does not appear at the surface. The trap also differs somewhat in appearance from the Palisades diabase. As mapped by Kümmel, the area measures about 2 miles in maximum diameter from northeast to southwest and is about 1 mile wide. It is thus sufficiently large to permit the location of many quarries within its bounds, although as yet undeveloped. The rock is very fine-grained and is somewhat vesicular in places; it may be a surface development of the Palisades diabase.

SUFFERN, ROCKLAND COUNTY

Union Hill, near Suffern, consists of a mass of trap from one-fourth to one-half of a mile in diameter. The rock is a fine-grained, compact diabase of the same composition as the Palisades rock. The Ramapo Trap Rock Co. has opened quarries in the exposure for the production of crushed stone.

PORT RICHMOND, RICHMOND COUNTY

The southern end of the Palisades diabase is found on Staten Island where the intrusion forms a low ridge that extends south-southwest from Port Richmond. The exact limits of the area are not well marked, but it probably is from one-fourth to one-half of a mile wide and terminates somewhere near Linoleumville. Quarries have been opened at Graniteville and Port Richmond. For the last few years they have been inactive.

Section 5

THE OCCURRENCE OF PEGMATITE IN NEW YORK

GENERAL FEATURES, FIELD RELATIONS AND USES OF PEGMATITES

The coarsely textured modifications of granite that are called pegmatites have a special interest that seems best to recognize here by their separate description. This interest is connected not only with their scientific features in regard to origin, methods of occurrence and mineral contents, but also with their industrial uses which cover certain fields quite apart from those belonging to ordinary granites. Pegmatites are sources of feldspar, quartz and other minerals of commercial importance.

The most striking physical character of pegmatites — their coarseness of texture — is a relative one, but important in determining their utility. Almost every variation may be found in the field between the coarser granites which are available for constructional or ornamental stone to the coarsest "giant" granites or pegmatites in which the individual minerals attain dimensions of several feet and weights of a ton or more. It is evident that other things being equal, the larger the size of the crystals, the more readily can their separation be carried out, and ease of separation is an important factor in the success of quarry operations for the production of feldspar and quartz.

Pegmatite is commonly associated with granite in its field occurrence. It is rare enough to find any large granite exposure without more or less of pegmatite either as included bodies or as distinct but apparently related intrusions in the surrounding country. The relation is so constant as to lead to the view already expressed earlier in this report that pegmatite is really but a modified form of granite, the textural differences being ascribable to variations in the process of crystallization. The presence in pegmatites of minerals containing fluorine, chlorine, boron, water, and other ingredients that are regarded as powerful solvents or "mineralizers," is significant. It appears very probable from this and other considerations that the rock represents the residue of a granite magma that was still held liquid after the main body had reached its consolidation temperature. This residue would tend to gather in the lower part of the magma as a result of the forcing out of the solvents from the cooling and crystallizing zone above. With the solvent vapors, some of the silica, alkalies etc., would be retained in a condition facilitating their ready migration through any favorable channels that might be formed by the fracturing of the overlying rocks. The formation of pegmatite dikes is thus a normal after-effect of an igneous intrusion. As regards their mineral nature, there seems to be a gradation from a composition about that of granite to very quartzose phases and even to pure quartz. The occurrence of many quartz veins in the vicinity of granite intrusions may thus be explained.

Forms of pegmatite bodies. Pegmatite intrusions commonly occur in tabular masses which are called dikes when they occupy vertical or highly inclined fissures, or sills if they follow channels in a nearly horizontal plane. Their direction is determined by lines of structural weakness in the country rock, such as faulting, jointing and in the case of sediments oftentimes by bedding, whichever structure may afford the easiest outlet toward the surface. Dikes and sills are sharply defined in contact with the country rocks. Though exceedingly numerous in the vicinity of granite masses, they only rarely attain a workable size. Their length naturally exceeds their thickness and it is rather seldom that the latter reaches more than a few feet.

Of more importance for quarry purposes, at least in this State, are the bosses and stocks of pegmatite that are characterized by a rounded or lenticular form as seen on the surface. Like bosses of ordinary granite, they seem to have made their own outlet toward the surface rather than to have followed some preexisting structural channel. They are more or less irregular in their boundaries, but in a general way approach an equidimensional form as seen in outcrop. They are well defined along the contact with the country rocks. They reach diameters of several hundred feet, as instanced by some of the occurrences in the eastern Adirondacks. They seem to be specially developed in the harder, more massive gneisses and in the granites themselves, whereas dikes occur both in these rocks and in the schists and sedimentary foundations, but are more characteristic perhaps of the latter.

Besides intrusive pegmatites, there are bodies occurring in the older granites and gneisses which seem to have originated in place by some process of differential crystallization while the magma was cooling; or in the case of gneisses they may have been found during a period of resoftening of the rock mass incident to metamorphism. They are of varied shape and size, often consisting of narrow bands that shade off on all sides to the parent rock or in large masses that are bordered at times by fine-grained aplitic granite. Pegmatites of this nature have no economic importance as sources of feldspar or quartz, as the minerals are not sufficiently large or segregated to admit their easy separation.

The feldspar minerals. The general mineral composition of pegmatites has been given on pages 66 and 67 of this report. It should be noted, however, that feldspar, the principal economic product of the local pegmatites, is not a definite mineral species, but rather a mineral group, the members of which vary among themselves in chemical and physical properties, as well as in their industrial uses. The requirements for pottery spar, for which a fairly large and steady market exists, are such as to exclude all but a few varieties, and similarly there are certain restrictions generally upon the kinds that find use in other industries. It is therefore highly essential to ascertain the nature of the feldspar in pegmatite and its adaptability for different purposes before undertaking the development of a deposit.

The feldspar minerals are composed of silica and alumina with one or more of the bases — potash, soda and lime. It is usual to class them in two principal groups, the potash feldspars and the lime-soda feldspars, according to the nature of the bases present.

The potash feldspars correspond chemically to the formula, $KAlSi_3O_8$ or $K_2O.Al_2O_3.6SiO_2$; accordingly when pure they should contain silica 64.7 per cent, alumina 18.4 per cent and potash 16.8 per cent. As a matter of fact, the potash seldom reaches the theoretical proportion, being partially replaced by soda which enters into the chemical structure or is contained in another kind of feldspar intergrown with the potash variety. The amount of soda present may range from 1 to 5 or 6 per cent. The potash feldspars include orthoclase and microcline, the former monoclinic and the latter triclinic in crystal form. Their distinction requires accurate measurements of the cleavage or interfacial angles, or a study of their optical properties under the miscroscope. Microcline is the more common variety in New York pegmatites. There is no difference in their value for pottery or other uses.

The lime-soda group of feldspars, or the plagioclases, consists of a continuous series that ranges from the pure soda variety, or albite, at the one end to the lime feldspar, anorthite, at the other. The composition of albite is represented by the formula $NaAlSi_3O_8$ or $Na_2O.Al_2O_3.6SiO_2$, corresponding to the following individual percentages: silica 68.7; alumina 19.5; soda 11.8. Anorthite has the composition $CaAl_2Si_2O_8$ or $CaO.Al_2O_3.2SiO_2$ and contains in percentages: silica 43.2; alumina 36.7; lime 20.1. The intermediate members are mixtures of the two in various proportions which can be expressed in general terms as $Ab_n An_m$. They include oligoclase, andesine, labradorite and bytownite, named in order from the soda to the lime end of the series. The feldspars with high percentages of soda are called the acid series on account of their relatively large proportion of silica in contrast with those high in lime, which are relatively low in silica. The identification of the different members requires accurate crystal measurements (all belong to the triclinic system but differ individually in form), or optical study, or chemical analysis, and the methods need not be explained here. The plagioclases commonly exhibit a striated appearance on certain faces which arise from minute parallel lines that mark the contact of lamellae in reversed or twinned position. This characteristic is not common to the potash feldspars.

The color of the feldspars exercises no influence upon their use, except as it may be due to the presence of iron stain or iron-bearing impurities. The potash feldspars commonly are light yellow, pink, red or gray in color. The color of plagioclase varies from pure white, most often seen in albite, to gray, brown or greenish, and less commonly reddish. The variations in natural color disappear when the feldspar is fused, the melt being usually white.

The use of feldspar in pottery and generally for glazing purposes is conditioned by the chemical composition which determines the temperature of fusion. The potash varieties, orthoclase and microcline, and the soda variety, albite, have the lowest melting temperatures. According to the more recent work of Day and Allen,[1] who carried out a very extensive series of experiments on the subject, these varieties do not melt at a definite point, but their fusion extends over a range of temperatures. In finely powdered microcline there was evidence of sintering at 1000° C., but the material was not actually fused until the temperature reached about 1300°. Albite fused at a somewhat lower point, but still above 1250° C. The lime-soda varieties melt at temperatures between 1340°, the fusing point of oligoclase, and 1532°, which is the melting point of anorthite.

Besides their lower fusing point, the feldspars that contain high percentages of alkalies possess a further important feature, namely, that on melting they yield a translucent glass. The varieties high

[1] Carnegie Institute Publications No. 31, Washington, 1905, p. 13-75; also Amer. Jour. Sci. 4th ser. v. 19. 1905, p. 93-142.

in lime, on the other hand, possess a strong tendency to crystallize and only consolidate in glassy form when quickly cooled. The crystallizing property becomes more marked with increase in the lime and is very strong in anorthite. This feature, of course, operates against the use of the more basic feldspars in pottery wares.

Uses of pegmatite. The products of the local pegmatite quarries include feldspar of different grades, quartz, mica and unsorted crushed pegmatite.

The uses of feldspar are various. The principal demand for high-grade potash spar is in the pottery industry, particularly in the manufacture of porcelain, semiporcelain and china tablewares, and porcelain sanitary wares and electrical supplies. The feldspar for such purposes should contain no more than a mere trace of iron, and very little muscovite or other mineral impurities except quartz, which is allowable up to a certain extent. In such wares it performs a double function, being employed to bind together the quartz and kaolin that constitute the body and also as a constituent of the glaze when this is required. The proportion of feldspar used in the body of vitrified wares ranges from 10 to 35 per cent and in glazes from 30 to 50 per cent. Bastin states[1] that the requirements in regard to allowable percentages of free quartz differ among individual potteries; a few manufacturers of high-grade wares demand a feldspar with less than 5 per cent of free quartz, but most potters perhaps use the "Standard" ground spar carrying 15 to 20 per cent of admixed quartz.

Manufacturers of enamel ware, glazed brick and terra cotta consume considerable quantities of feldspar. In enamel ware, the requirements are perhaps not so strict in regard to iron as in pottery manufacture, but the spar must be fairly free of quartz, as the latter tends to raise the melting point. Among enamel ware and terra cotta manufacturers, a preference is shown for albite over the potash varieties owing to its lower fusing point. Little of this mineral is found in the New York pegmatites, but it occurs in quantity in eastern Pennsylvania and in Maryland. Another use for the local feldspar is in the manufacture of opalescent glass. This requires a material of about the same quality as that for enamel ware, but may contain more quartz.

A large quantity of feldspar is employed as an abrasive, especially in the form of scouring soaps and powders. For that

[1]Feldspar Deposits of the United States, U. S. Geol. Sur. Bul. 420, 1910, p. 19.

purpose it is ground to an impalpable powder. It also finds use in the manufacture of abrasive wheels as a binder for the emery or carborundum with which the spar is mixed.

The quartz, which is an important ingredient of the local pegmatites, has value if obtainable in fairly pure condition. It is extensively produced at the Bedford quarries. The principal uses are in pottery and in the manufacture of abrasives and wood filler. The requirements for pottery are strict with regard to iron, but less so for other uses. The quartz from pegmatites may be regarded as a by-product, not of sufficient importance to warrant quarry operations for itself alone. Larger amounts of quartz come from quartz veins.

The unsorted pegmatite, when crushed, finds sale among makers of prepared roofing, in which it is employed as a surface coating with tar or some bituminous binder. The pegmatite is crushed to a pea size or a little coarser, the feldspar and mica yielding flat surfaces that are of advantage in securing firm adherence to the paper. The purity of the material is a subordinate factor and no effort is made usually to separate any of the ingredients. The fine material resulting from the crushing is sold for use in concrete and grout, and a small proportion in the coarser sizes finds a market as poultry grit. Crushed pegmatite has recently come into use in the preparation of artificial stone which is made to imitate granite and is cast in almost any form so as to require little or no dressing.

General considerations. The economic value of pegmatite occurrences depends upon a number of features, some of which have been mentioned already. The character of the feldspar will determine the adaptability of the product to different uses. In case the minerals are much intergrown, even if in fairly large individuals, the material can hardly be sold for the higher grades without so much expense in sorting and cobbing as to render the operations unprofitable. Such occurrences are adapted only for the production of unsorted pegmatite for roofing and concrete. To enable them to be worked profitably, they must be of large size and conveniently situated for shipment of the product to market.

Under the varying conditions presented by the occurrence and mineral nature of pegmatites, there is little that can be stated generally in regard to the value of undeveloped properties. As a rule, it may be said that a dike or lens less than 25 feet thick is not workable and one of that size can be worked profitably only under exceptional circumstances. Of course, much depends upon distance of haulage and the freight rates to market.

There is considerable uncertainty as to the quantity of available material in pegmatites, even when they have been well exposed at the surface. Unlike normal granites, they are very liable to sudden variations in the proportions and relations of the quartz and feldspar, such variations arising quite abruptly. This involves a considerable element of risk, particularly in the working of small bodies for some particular grade of feldspar. In the larger dikes and bosses, the desired quality may be obtained by carrying on work in several places and sorting the product carefully into grades. Thus at Bedford three grades of feldspar are produced from one body, besides a quartz by-product. With a small output, it is not practicable always to sort the product so carefully and there is consequently more waste.

THE LOCAL DISTRIBUTION OF PEGMATITES IN NEW YORK STATE

The pegmatites are limited in their occurrence to the two principal areas of early crystalline rocks represented by the Adirondacks and the southeastern Highlands. They occur in the vicinity of the larger granite intrusions, but the workable bodies are more often found on the periphery of such intrusions and within the older country gneisses and schists than in the midst of the granites themselves. They appear sometimes in the areas where ordinary granites do not outcrop, but in this case they may be offshoots of some buried mass that were able to reach the surface on account of their fluid condition.

The Adirondack region is well supplied with pegmatites, but they are by no means equally distributed. The great anorthosite mass that spreads over the eastern central part, mainly within Essex county, is naturally devoid of occurrences, as it is of later intrusives generally, except those of basic character. In the fringe of gneisses to the east of that mass there are granite intrusions and pegmatites, some of the latter of large size, as those near Crown Point and Ticonderoga. In the northern Adirondacks, which is largely occupied by a belt of very old gneisses, few intrusions of younger granite are encountered. So far, only one large pegmatite body has been reported in that section. The southern Adirondacks have a number of occurrences and it may be expected that others will be found here as the region is more carefully explored, but they are likely to be in the more inaccessible parts. The western Adirondacks, particularly the section included in St Lawrence, Jefferson and northern Lewis counties, is known to include numerous bathyliths and bosses of granite, covering a larger portion of the surface than in any other part; the granites are mainly coarse varieties, rich in quartz and containing segregated masses of pegmatite. The conditions thus appear very favorable for the occurrence of extensive bodies in that section, but the remote and inaccessible nature of much of the area has rather discouraged exploration.

In the Highlands region and southward into Westchester county pegmatites are quite abundant but only rarely reach workable proportions. They occur mainly in the Precambric gneisses, but may be of much later age than the latter as the granite invasions continued down into Siluric time. The principal bodies that have been worked are near Bedford, Westchester county. In the central Highlands there is much pegmatite and coarse granite in evidence, usually pinkish or grayish in color, but there are no developed quarries. The pegmatites occur in considerable bodies in the vicinity of some of the magnetite deposits.

The present description of the pegmatite localities includes mention of all of present or prospective importance that have come to the writer's attention during rather extended travels in the field. A few have been mentioned in previous reports of the State Museum, and many of the better known occurrences are given detailed treatment in Bastin's monographic bulletin, "Economic Geology of the Feldspar Deposits of the United States," already cited.

CROWN POINT, ESSEX COUNTY

Quarry of the Crown Point Spar Company

The pegmatite quarry worked by the Crown Point Spar Company is on Breed's hill, south of Crown Point, about 1¼ miles west from Lake Champlain. The pegmatite outcrops on one of the summit knobs, 500 feet or more above the lake level. It was discovered some years ago by Charles Wait of Crown Point, the present manager in charge of the quarry. It is apparently a large, somewhat irregular lens or stock, with a longer diameter running northeast-southwest parallel to the general tend of the surrounding gneisses. The full size is not revealed, but it measures several hundred feet at least in that direction. Toward the border it becomes finer grained. The country gneiss is a dark, banded variety, much of it an amphibolite, and is intruded by aplite and pegmatite. Small masses of the latter may be observed, which approximate the shape of the larger body; they are irregularly bounded and contain patches of the country gneiss that have been torn away from the walls.

The pegmatite consists of two varieties of feldspar, one a light pink and the other greenish; also quartz and biotite, with occasional small crystals of titanite, magnetite, zircon, tourmaline, pyrite and

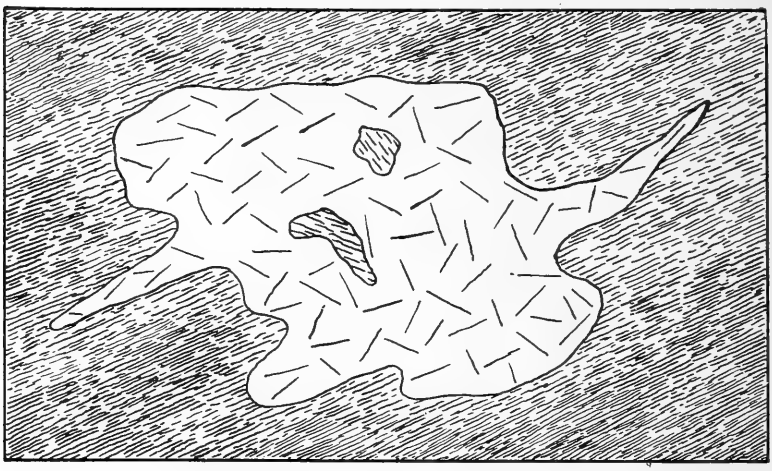


Fig. 13 Intrusion of pegmatite in gneiss, near quarry of Crown Point Spar Co., showing the bosslike shape of the pegmatite masses in this section

chalcopyrite. Bastin reports also the presence of allanite. Chlorite occurs as a secondary development along planes of slipping incident to compression. The quartz and feldspar are rather intimately intermixed, but single individuals of either occur up to 6 or 8 inches in diameter. An examination of the feldspars under the microscope show that the pink variety is microcline and the greenish a plagioclase in optical properties close to oligoclase. Most of the iron is present in biotite which is rather abundant though unequally distributed.

The principal product of the quarry is roofing material but other grades are sold for concrete, poultry grit and enamel wares. The spar for the latter purpose is obtained from sorted material that is free of iron minerals, with microcline as the main ingredient. The biotite is screened out and finds application in paint.

The pegmatite as quarried is conveyed by an overhead tram to the mill which is situated at the base of the hill close to the lake and railroad. It is there passed through a preliminary crusher of the Blake type, then dried and further reduced by rolls and sized on screens. The pottery grade after crushing and drying goes to a chaser for final reduction. The crushed pegmatite is graded into six sizes of which the coarsest (no. 2) will pass a 2½ mesh screen and is caught on a 3½ mesh screen, and the finest (no. 6), which is like very fine sand.

Roe's quarry

Roe's quarry, locally known as Roe's spar-bed, is about 8 miles northwest of Crown Point in the vicinity of Towner pond, near the Moriah town line. The locality more precisely is three-fourths of a mile directly south of Towner pond and one-fourth of a mile east of the highway leading past the pond. It is in a very rugged section, quite close to the main anorthosite intrusion, lying well up on a ridge at an elevation of between 1100 and 1200 feet, according to the contour map.

The property was last worked fifteen years or more ago as a source of pottery spar. The output, which must have been considerable in view of the size of the quarry working, was hauled to Crown Point for shipment at a cost of from $1.25 to $1.50 a ton. The property now belongs to H. W. Willcox of Crown Point.

The opening in its present condition is 75 feet wide running northeasterly into the ridge and has a face 50 feet high. Apparently the body has the shape of an elongated lens, from 75 to 100 feet wide and of uncertain length. The bounds are not clearly revealed by outcrops and there is some doubt as to the extent of the pegmatite outside of the part worked. The longer axis appears to run about N. 50° E. as indicated by a series of test pits below the main opening. Above or northeast of the quarry the country rock, a grayish hornblende gneiss, outcrops within a short distance of the line of strike, so that apparently there is not much more to be quarried in that direction. A large supply exists, however, in the floor of the quarry which could be conveniently worked, and probably also good material would be found to the southwest. The existence of feldspar on the adjoining property to the south of the Roe quarry was reported to the writer, but the locality was not visited.

The feldspar occurs in very large crystals and aggregates, well segregated. Individuals with a cross-section of 3 feet are not uncommon. Some show fine crystal boundaries as they project from the walls of the quarry. There are two varieties of feldspar present, pink and grayish white, the former showing the properties of microcline and the latter of oligoclase. They appear to be in about equal amounts. Quartz occurs in subordinate quantity and is unequally distributed, being practically absent over considerable areas. It is pink or milky in color. Graphic intergrowths with feldspar are in evidence, but the proportion is small. Of iron-bearing silicates, biotite and black tourmaline are fairly common, but for the most part are segregated in bunches, so that their presence would not entail any great waste in sorting for pottery materials. Altogether the pegmatite is exceptionally adapted for the production of feldspar.

The face of the quarry is cut by four trap dikes, from 1 inch to 2 feet thick, which are quite closely spaced and probably coalesce below.

The main difficulty in the way of successful operation of the quarry seems to be its remoteness. The nearest outlet to the railroad is by way of Crown Point over a rather rough country, but with the grade favoring the load.

Penfield Pond occurrence

A body of pegmatite of large size occurs on the road leading west from near the south end of Penfield pond. It was noted by the writer several years ago, but was not examined with regard to the quality of the materials.

In the report by Dr Ida H. Ogilvie on the Paradox Lake quadrangle,[1] it is stated that pegmatites are abundant in the vicinity of Crane pond.

TICONDEROGA, ESSEX COUNTY

Quarry of Barrett Manufacturing Company

The Barrett Manufacturing Company has operated a quarry near Ticonderoga for several years past, using the crushed pegmatite in the preparation of sheet roofing. The quarry is situated about 2 miles northwest of the village of Ticonderoga at the eastern base of the ridge of Precambric rocks. The occurrence is very similar to that described near Crown Point, consisting of a large lens of pegmatite included within gneisses of the Grenville series with the larger axis parallel to the strike of the latter, which is about N.55°E.

The pegmatite is made up of quartz and feldspar which are not very well segregated and do not attain large size, the individual crystals being seldom more than 4 or 5 inches across. The feldspar consists of two varieties, the more abundant being a white or grayish microcline. The second variety is a light green oligoclase. Intergrowth of the quartz and feldspar is the usual condition. The

[1] N. Y. State Museum Bul. 96, 1905, p. 488.

principal iron mineral is biotite, which forms rather large crystals but is very unequally distributed. There is some secondary chlorite. Black tourmaline, garnet and iron sulphides occur sparingly. The character of the pegmatite thus agrees very closely with the Crown Point occurrence and is no doubt connected with the same series of granite intrusions.

The product of the quarry is reduced in a mill nearby, equipped with jaw crusher and rolls and screens for sizing. The material too fine for roofing is sold for concrete and grout. No pottery grades are obtained. The output is hauled by wagons to Ticonderoga for shipment.

Mount Defiance quarry

An abandoned quarry is found on the north end of Mount Defiance between Montcalm Landing and Ticonderoga. It was worked several years ago by the Ticonderoga Feldspar Co. The rock strictly is not a granite pegmatite, but a coarse phase of the country gneiss which belongs to the syenitic class. It contains hornblende and pyroxene with some quartz and a perthitic feldspar.

FORT ANN, WASHINGTON COUNTY

Ashley quarry

An exposure of pegmatite near Fort Ann has been worked at different times for feldspar and quartz. It is one of the localities from which quartz was obtained for grinding at the mill that was operated at Fort Ann about twenty-five or thirty years ago. More recently it has been a source of feldspar and has been worked intermittently according to the prevailing market demand, the last time by Dominick Ashley of Glens Falls.

The outcrop lies about 2½ miles northwest from Fort Ann at the base of the gneiss ridge, of which the higher part is known as Putnam mountain. It is on or adjoins the farm of Ira D. Gilmore. It consists of a rather irregular area, suggesting somewhat a lens, with a longer axis nearly at right angles to the trend of the ridge or to the northwest. An open pit about 125 feet long and from 30 to 40 feet deep has been made but is now largely filled with water. The lens is broadest near the southeastern end where it measures fully 75 feet across. To the northeast it gradually diminishes and wedges out in the gneiss 50 feet beyond the end of the pit. The gneiss wall rock is a laminated biotite variety that may be classed with the Grenville series.

The pegmatite contains much graphic intergrowth of feldspar and quartz, although the two minerals also occur separately to a considerable extent.

The quartz masses reach a diameter of 2 or 3 feet and the feldspar a similar size. Most of the feldspar has a grayish color and belongs to the microcline variety. There is also a little pinkish feldspar which may be orthoclase. Tourmaline and the iron-bearing silicates generally have a very limited representation, though the material is much stained by iron oxides, the result probably of oxidation of sulphides.

The pegmatite shows alteration in places, with the formation of kaolin and sericite, and takes on a greenish coloration which seems to be traceable to secondary serpentine. The presence of this mineral is not connected apparently with any magnesium compound of the pegmatite, but is referable to the alteration of the feldspar and to the introduction of magnesium compounds from outside sources. Apparently the pegmatite has been a channel for ground water circulations.

CHESTERTOWN, WARREN COUNTY

Wilson Brown quarry

The name of this quarry is given on the authority of residents of Chestertown, who stated to the writer that the property was last worked about fifteen years ago. The purpose of the operations originally was the production of mica. The locality is 3 miles south of Chestertown on the north side of a high ridge 1½ miles east of the Warrensburg road. Two workings may be seen, the principal one being to the south and higher up on the ridge. This consists of an open cut about 50 feet long and 15 feet wide on a dike or elongated lens of pegmatite that strikes northeast. The limits of the body are uncertain, except on the east side of the pit where the country rock appears within a few feet of the wall. The more northerly pit is probably a separate body, unless the pegmatite has a much larger extent than seems to be indicated. It is a narrow opening of undetermined depth.

EDINBURG, SARATOGA COUNTY

Gordon quarry

In 1906 the Claspka Mining Company of Trenton, N. J., opened a quarry in the town of Edinburg, Saratoga county, which the company worked for two or three years for pottery spar. The locality of the quarry is 2 miles north of Batchellerville, on the road to Day, on the farm of Adelbert Gordon. The nearest railroad point is Northville, the northern terminus of a branch that connects at Fonda with the New York Central lines, necessitating a wagon haulage of 8 or 9 miles over a somewhat rough country.

There are two openings on the property, situated about one-fourth of a mile east of the highway at the base of the ridge which forms the steep eastern slope of the Sacandaga river valley. The lower or westerly pit has been worked to a depth of about 50 feet. Its horizontal dimensions are about 75 feet by 50 feet, indicating the usual stock form in which most of the larger bodies of pegmatite occur, but the whole area of the pegmatite is not shown. The minerals are in coarse crystals and fairly well segregated, though there is considerable graphic intergrowth of quartz and feldspar. The former is found also in pure masses of white and pink color up to a foot in diameter. The feldspar is mostly grayish microcline, but is intergrown to some extent with a white variety which microscopically corresponds to albite. The largest individuals observed were fully 3 feet in length. Much waste in quarrying was incurred from the presence of abundant mica and owing to the existence of an included lens of the wall rock. A large quantity of quartz, mica and mixed material was left at the quarry after the feldspar had been sorted for shipment.

A feature of this quarry is the fine crystals of muscovite and beryl which occasionally attain very unusual dimensions. The muscovite forms books and columnar crystals that measure a foot or more in diameter and from an inch or so to 10 inches thick. The mica, however, is not generally suitable for cutting as it shows rulings and contains inclusions of iron oxides. The beryls are the largest that have been found in the State; one crystal, now in the State Museum, has a length of 27 inches and a diameter of 10 inches. The larger ones are opaque and greenish in color, but some small crystals have been found that were fairly clear aquamarines. They show the hexagonal prism faces but are not terminated.

A second pit lies to the east of the one described and is of smaller size. The pegmatite has the same general character as noted but shows some garnet.

There appears to be a good body of pegmatite at this place, though the contact against the country gneisses is not so well disclosed as to permit an estimate of the exact size. The gneiss is a biotite variety with augen of feldspar and shows a foliation that strikes about N. 50° E. and dips 30° southeast. Apparently the pegmatite does not conform to the structure of the gneiss, but breaks across the foliation, which it would naturally do if it were in the nature of a stock rather than a dike.

The occurrence still possesses value for the production of pottery spar. The main drawback at present is the expense of haulage.

CORINTH, SARATOGA COUNTY

Quarry of American Feldspar & Milling Co.

This quarry is a practically undeveloped property from which only trial shipments have thus far been made. The Corinth Feldspar Co. did some work on it in 1908, but relinquished control to the company named, who are its present owners. The property is about 3 miles southwest from the Corinth railroad station and 700 feet above it.

The pegmatite has a width of about 60 feet and is exposed over a vertical distance of 130 feet. It has not been sufficiently developed to indicate the shape of the body, but it is perhaps an elongated lens or dike intruded parallel to the foliation of the surrounding gneiss which trends a little west of north. There is more or less of the rock in evidence over a distance of 2000 feet. The pegmatite consists mainly of an intergrowth of quartz and feldspar, with only a small part of either mineral in free crystals serviceable for pottery uses. The feldspar is an untwinned variety that appears to be orthoclase, a rather rare form for Adirondack pegmatites. There is considerable biotite which is so equally distributed as to render its separation a matter of difficulty.

MAYFIELD, FULTON COUNTY

Tyrell quarry

This occurrence of pegmatite was worked a few years since by the Claspka Mining Co. along with the quarry near Batchellerville. It is situated in the town of Mayfield, 3 miles west of Cranberry creek, on the farm of Richard Tyrell. The outcrop lies well up on the gneiss ridge, 800 or 900 feet above the railroad which terminates at Northville, 5 miles above Cranberry creek.

The main body of pegmatite is opened by a pit 50 or 60 feet across and heading into a ridge in a northeasterly direction. The quarry face as left by the former operations is over 50 feet high. The materials are coarsely crystallized, the quartz and feldspar reaching a maximum diameter of 3 or 4 feet. The feldspar includes pinkish microcline and a white striated albite. The latter is usually predominant, while the microcline is so much intergrown with biotite as to cause much loss in sorting. There is also a little of greenish gray oligoclase. On the east side of the quarry a trap dike intervenes between the pegmatite and the country gneiss. Biotite and tourmaline are the iron-bearing impurities. The latter is in small amount, associated more especially with the quartz. The biotite is rather abundant and in large crystals.

It would appear that the spar from this quarry might prove very serviceable for enamel ware and for glazing brick and terra cotta, for which purposes albite is considered preferable to the potash varieties on account of its lower fusing point.

There are several places in the vicinity of the quarry where pegmatite outcrops. One showing is just northeast, a ledge 30 or 40 feet long, with reddish feldspar and some biotite. An 8-foot dike occurs just west of Mr Tyrell's house and contains reddish feldspar and pink quartz, with little mica or other dark silicates. The locality may be considered one of the more promising places for exploration for feldspar in this section.

DE KALB, ST LAWRENCE COUNTY

Rowland property

The existence of a ledge of coarse pegmatite in the town of Bigelow, St Lawrence county, was brought to the writer's attention some time ago by J. H. McLear of Gouverneur. The occurrence is 3 miles northeast of Bigelow, between that place and East De Kalb. It is exposed in natural outcrops rising in low ridges above the general surface. One of the ridges is on the Rowland farm and another occurs on an adjoining property. They are conspicuous objects on account of the white color which is contributed both by the feldspar and the quartz.

The principal ledge is about 75 feet long and 40 feet wide, but these measurements are based on the actual exposure and the body is undoubtedly considerably larger, as there is no evidence of any walls where the pegmatite disappears below the surface. A second ledge is found 300 feet southwest of the first, practically in the direction of the longer axis of the first; and the pegmatite is said to be exposed in other places which, however, were not seen by the writer. There is little doubt that the occurrence represents a large mass of the pegmatite, but whether in a single body or in two or more bodies is not apparent.

The exposures reveal fresh, unaltered rock from the very surface. There is no iron stain and practically no iron silicates are in evidence, though an occasional grain of pyrite occurs in the quartz. The latter is milky white and forms unmixed masses, but mainly occurs intergrown with the feldspar. There is only one kind of this mineral, so far as could be established from a hasty examination; the feldspar is white perthitic microcline that might readily be mistaken for albite except for the lack of striations. The microcline on close examination shows a very fine intergrowth with another feldspar, also white, that has the optical properties of albite. There is perhaps one-fourth as much albite as microcline. The included bands of albite are approximately normal to both cleavages. The feldspar occurs in crystals from 6 inches to 3 feet long. It is probable that a fair proportion of first-grade pottery spar could be secured, but the larger quantity would have to be graded, however, on account of the quartz. This opinion is based, of course, solely upon the surface showing and there is need of careful prospecting before any attempt is made to extract material for shipment.

The ledges are only slightly above the ground level and a quarry would soon develop into a subsurface working that would require draining. The conditions otherwise seem favorable for economical work. The railroad passes within one-fourth of a mile of the property.

FOWLER, ST LAWRENCE COUNTY

Denesia property

A dike of pegmatite with well-crystallized feldspar occurs on the farm of C. W. Denesia about 2 miles south of Fullerville, in the town of Fowler. There is a single exposure which seems to be of a dike, but it is too limited in area to permit much certainty regarding the nature and size of the body. The outcrop is only 8 feet wide. With the very small area of rock exposed there is a probability that the occurrence may be of greater importance than is at present indicated. The feldspar occurs in splendidly developed crystals from 2 to 3 feet long, inclosed in a groundmass of intergrown quartz and feldspar with which tourmaline and biotite are associated. It consists of a deep red microcline and also of a lighter pinkish variety that is an intergrowth of microcline and albite.

FINE, ST LAWRENCE COUNTY

Scott property

There are several occurrences of pegmatite on the Fred Scott farm, 4 miles north of Oswegatchie, in the town of Fine, St Lawrence county. They are of interest for the associated minerals as well as for possible supply of quartz and feldspar. The feldspars occur in pink, white and greenish colors, evidently including both potash and lime-soda varieties. They are seldom found in segregated masses or crystals, but are mostly intergrown with quartz and some of the other minerals. Among the mineral species represented are fluorite, hornblende, pyroxene, pyrite, chalcopyrite and titanite, some being well crystallized. The association suggests a granite contact with limestone, and in fact the latter rock is found in scattered patches in the vicinity.

BEDFORD, WESTCHESTER COUNTY

Quarry of P. H. Kinkel & Sons

The body of pegmatite situated in the hill southeast of Bedford village has for a number of years furnished a very large part of the feldspar and quartz production of the State. Besides the four openings included in the Kinkel quarry, the Bedford Feldspar Co. has recently developed a new quarry on the same body. The occurrence is notable not only for its size, but for its good examples of crystallized and rare minerals and for the varied conditions presented by the mineral association in different parts of the exposure.

The several openings in the Kinkel quarry lie along the eastern and northern sides of the hill, the original pit being on the east side near the present mill. At this point the pegmatite shows more or less disintegration from surface weathering, so that operations have not been as actively carried on here as in the other pits higher up on the hill slope. These include two very large pits of which the more southerly one is about 300 feet long, 150 feet wide and has a face up to 50 feet high. The central one is not quite so long and the more northerly one is about 100 feet long, 50 feet wide and 35 feet in greatest depth. Between the different pits and even in parts of the same working a marked variation may be observed in the arrangement and character of the pegmatite minerals. Though feldspar is the main component throughout most of the exposure, it gives way in places to a nearly pure quartz aggregate. Quartz is particularly abundant in the central part of the southern pit where it occurs in a large zone which here and there incloses a crystal or mass of pink feldspar. On either side of the quartz zone for some distance occurs a mixed phase of quartz and albite in pegmatitic intergrowth, with occasional segregated individuals or masses of the pink feldspar, which is microcline. The pink feldspar occurs by itself also in considerable bodies. The white albite is mainly developed as a graphic intergrowth with the quartz. Between the different phases exhibited by the feldspar, quartz and intergrowths of the two, it is possible to have every gradation. The conditions seem to indicate more or less segregation of the constituents during the process of intrusion, facilitated no doubt by the extreme mobility of the magma. Lack of uniformity is rather characteristic of the larger pegmatitic bodies; and similar features may be seen in other occurrences though they are not so well shown as in these quarries.

The feldspar from the different workings is graded according to character and content of quartz. The microcline, which occurs mainly in quite pure crystals and aggregates, constitutes the first grade, suitable for pottery purposes. The albite that is fairly free of quartz, but not entirely so, is sold as enamel material. The pegmatitic intergrowth of albite and quartz, with more or less of the pink variety as well, is used in glass manufacture, scouring soaps, etc. The first grade has generally been sold in crude condition, as the mill until recently was not equipped for grinding pottery material. The others were ground at the quarries. Besides the feldspar, there are obtained large quantities of quartz, which is shipped crude to the Bridgeport Wood Finishing Co. for wood filler and silica paint material.

The more common associated minerals included mica, tourmaline, and beryl; occasional ingredients are garnet, ilmenite and some of the uranium minerals. The mica is principally muscovite and occurs as included crystals in the feldspar or in the finer pegmatitic intergrowths along with the feldspars and quartz. The crystals seldom exceed 5 or 6 inches in diameter. They are much fractured and scarcely suitable for cutting of sheet mica. The biotite is in larger crystals but not so plentiful as to give much trouble in its removal. The tourmaline is the common black variety; it is mostly associated with the quartz as well-shaped prismatic crystals and as a thin crystalline coating on the surfaces. The beryl forms flat and prismatic crystals, occasionally well-

Plate 24

Pegmatite quarry, Bedford. One of several openings on the property of P. H. Kinkel & Sons

bounded, reaching diameters of 6 or 8 inches. It is usually opaque, yellowish green in color. The rare compounds, autunite, cyrtolite and uraconite all of which contain uranium are listed by Luquer[1] as occurring at Bedford. The first-named occurs rather frequently as a bright greenish-yellow deposit on the feldspar and mica. The writer has recently observed the presence of columbite in crystalline masses of considerable size.

In connection with the quarry, P. H. Kinkel & Sons operate a mill for grinding the spar. The equipment consists of a breaker, chasers and screens with a pebble mill for the fine grinding of pottery spar. This is a recent addition, as formerly only the second and third grades were ground, for which purpose the final reduction was accomplished in a ball mill.

The output of the quarries is shipped from Bedford station on the Harlem branch of the New York Central, necessitating a haulage of 5 miles.

Quarry of Bedford Feldspar Co.

This new opening lies at the base of the hill and a few hundred feet north of the Kinkel quarry. The continuation of the pegmatite in that direction was concealed by a cover of soil and earth and was first explored by test holes before development work was begun.

The existence of the pegmatite rather indicates that the mass is not a dike in the usual sense of the word, but another of the rounded bodies or stocks that constitute the usual mode of occurrence of the larger masses. If a dike, it does not conform in direction with the general structure of the gneisses, but has a northerly strike. The great width of the body exposed in the Kinkel quarry is exceptional for a dike. It is possible that the present quarry is on a separate intrusion, but this scarcely seems likely in view of the character of the material.

The working is all below the ground level and when seen in the spring of 1913 was about 30 feet deep with a diameter of 75 feet. The pegmatite is the same coarse aggregate as found farther south but carries a larger proportion of feldspar than the average in the Kinkel quarry. The material is somewhat stained and decomposed, but fresher material should be found in depth.

[1] "The Minerals of the Pegmatite Veins at Bedford, N. Y." The American Geologist, v. 18, 1896, p. 259–60. Also American Geologist, v. 38, 1904.

The company has erected a mill on the property in which it grinds all the spar, shipping the ground material to tile, enamel ware and glass manufacturers. The capacity is 35 or 40 tons a day. The equipment for final grinding consists of ball mills. Auto trucks are used to transport the material to Bedford station, the shipments being made in bags.

Bullock quarry

The firm of P. H. Kinkel & Sons opened a new quarry in 1912 on the Bullock property about 2 miles south of their main quarries. The property is west of the Hobby quarry. The occurrence is very similar to the latter in the quality of the product but is not apparently connected with it. It consists of a dike 30 feet wide which strikes northeast and dips 80° to the northwest. The wall rock exposed on both sides is a mica schist, garnetiferous near the contact with the pegmatite, and resembling the Manhattan schist in its general appearance.

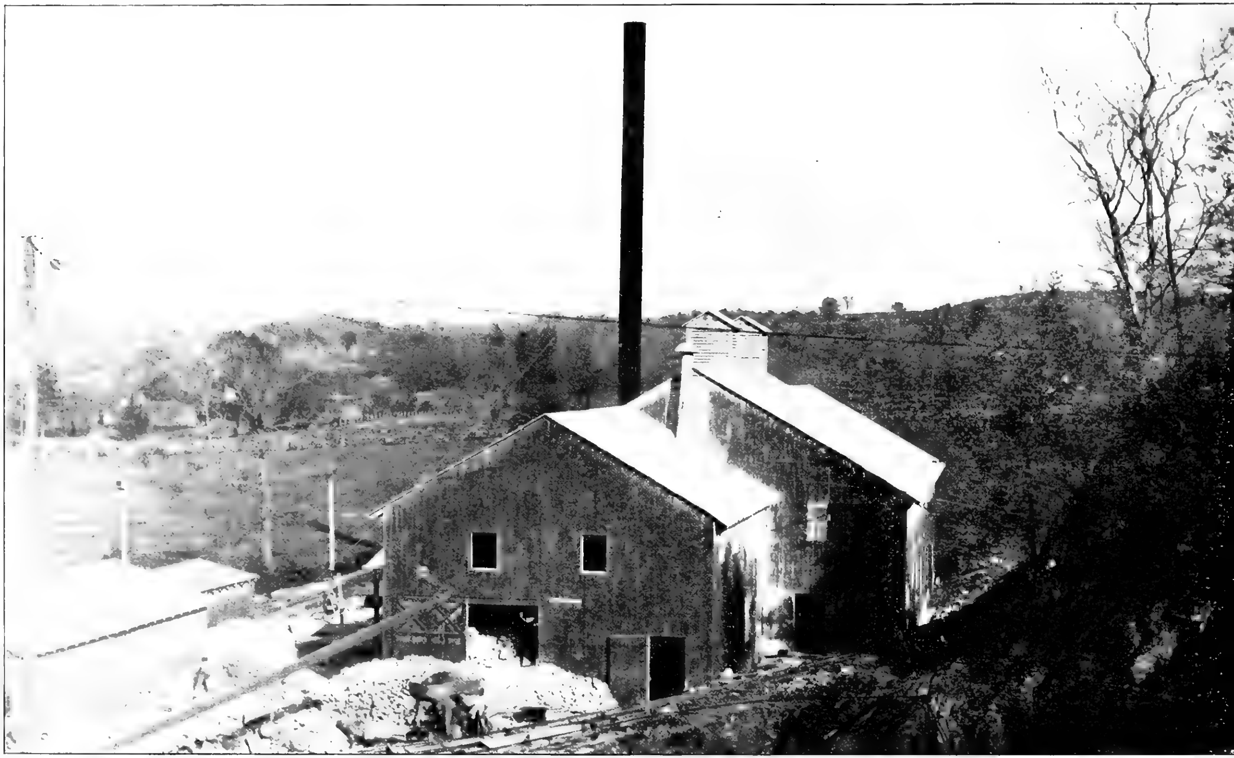
The pegmatite shows a high degree of mineral segregation with very little of pegmatitic intergrowth. It is mostly feldspar of a cream or buff color, which on examination is seen to be an intergrowth of microcline and albite with the former predominant in the proportion of 2 or 3 to 1. It occasionally shows good crystal boundaries. The individuals measure as large as 2 feet or so in length, but are mostly smaller. The quartz has a smoky color and near the contact shows crystals of garnet. Tourmaline and yellowish mica are in subordinate quantity. The feldspar is readily separated with little waste, so as to be shipped as no. 1 grade.

The opening is on the side of a hill and presents a face about 30 feet high. It can be deepened considerably before it is necessary to provide artificial drainage. The product has been shipped crude for abrasive uses, but is an excellent material for pottery or glazing. It is noteworthy that the same varieties of feldspar are represented as in the Bedford quarries, but occur in pegmatite intergrowths and not segregated.

Hobby quarry

The Hobby quarry lies a little east of the Bullock beside the Mianus river. It was worked for a time by Otto Buresch and later by P. H. Kinkel & Sons, but for the last few years has been idle. It appears to be based on a large body, though the contacts with the country rocks are not shown. The working is perhaps 150 feet long by 100 feet wide.

Plate 25



Quarry and mill of the Bedford Feldspar Company. The quarry pit is in foreground at extreme right

The pegmatite has the same character as that described for the Bullock property, but is somewhat coarser. Aggregates of feldspar 10 feet in diameter are found, as well as equally large masses of white and rose quartz. The conditions are thus excellent for the production of high-grade materials. The feldspar is cream colored and is made up of microcline with small albite bands. There is a small quantity of muscovite in scales and plates associated with it. Black tourmaline also occurs in limited amount. The property undoubtedly will be worked when the market affords sufficient inducement. The long haulage of 7 or 8 miles is the main drawback to operations at present.

Section 6

THE NEW YORK MARBLE QUARRIES

GENERAL CHARACTERS OF MARBLES

Marble, like granite, is a term used by quarrymen for a variety of rock materials. Any limestone that takes a polish or possesses ornamental qualities is a marble in the trade sense, and some of the softer silicate rocks are likewise thus designated, notably those having a serpentine base. More properly the name belongs to the crystalline or metamorphic class of limestones as distinguished from the compact to finely granular kinds occurring in the regularly bedded formations.

The quality of crystallinity is not always lacking in ordinary limestones, for some show aggregates of plainly visible calcite grains with the characteristic calcite cleavage surfaces; for example, the Chazy limestones of the Champlain valley. But their texture is never so completely crystalline as in the types that have undergone a metamorphic rearrangement of their constituents while subjected to compression in the depths of the earth. Such partially crystalline limestones often polish well, but lack the glint and translucency of true marbles. In this case, the presence of coarse crystalline calcite probably results from the working over of the finely divided particles by ground waters.

The microscopic appearance of a true marble is quite distinct from that of any carbonate rock which has not undergone pressure metamorphism. In the first place, the particles of calcite (or dolomite) are more uniform as to size and shape, whereas the texture of nonmetamorphic limestones is apt to be very variable and the size of grain shows a wide range. When crystallization takes place under conditions of cubic compression which characterizes the metamorphic process at considerable depths, the individual particles have not opportunity to develop the characteristic outward forms that calcite ordinarily assumes, but must accommodate themselves to the narrow space restrictions resulting from the simultaneous crystallization of the whole mass. As a consequence, they exhibit a more or less even, granular habit with curved or irregular boundaries which are closely matched together. A second characteristic of the metamorphic limestones as seen in thin section is the striations, broader than the lines of cleavage, that cut across the grains. These mark the junctions of crystals in so-called twinned positions; they are not found in calcite particles of ordinary bedded limestones.

In the metamorphic change from limestone to marble, the bedded structure as shown by the separation into parallel layers is usually obliterated. Marble normally has a massive appearance and is so coarsely jointed that blocks of almost any size may be quarried. It also lacks any definite cleavage, a feature that is of great advantage in the working of the stone.

Serpentine marbles include several types. Serpentine is a hydrated silicate of magnesia and iron, which has the same hardness as calcite. The associations of the two minerals, therefore, does not affect the capacity of a marble to take a polish. Verde antique is a serpentine irregularly veined with calcite. Another type consists of crystalline limestone in which occur scattered grains of serpentine of the size of peas, giving a white base speckled with green. Serpentine also occurs unmixed with carbonates and then exhibits oftentimes an attractive appearance by reason of variations in color which ranges from light translucent green to dark green and even black. Its origin is traceable usually to the decomposition of such minerals as pyroxene, amphibole and olivine. The larger bodies of serpentine are formed by the weathering of igneous rocks in which those minerals predominate.

MINERAL CONSTITUENTS OF MARBLE

Marbles may have either calcite ($CaCO_3$) or dolomite ($CaMgC_2O_6$) as the principal ingredient, or they may contain a mixture of the two in any proportions. A pure calcite marble would have the same composition naturally as the mineral itself, which consists of lime (CaO) 56 per cent and carbon dioxide (CO_2) 44 per cent. Theoretically, a dolomite marble should contain lime (CaO) 30.4 per cent, magnesia (MgO) 21.7 per cent and carbon dioxide (CO_2) 47.8 per cent. These percentages, however, are never found in commercial marbles, owing to the invariable presence of other ingredients. The highest grades of white statuary marble, as represented by the best Italian and Greek examples, carry, however, over 99 per cent calcium carbonate, and there are American marbles nearly, if not quite, as pure.

Between calcite limestones and the dolomites, every degree of gradation is to be found, since the two minerals intergrow with each other in any ratio; such mixed phases are commonly designated as magnesian marbles or limestones, as the case may be. There is no discernible difference in the outward appearance of a calcite limestone and a dolomite, and their distinction requires the use of chemical or microscopic methods. The slight difference in hardness is not a reliable criterion. The two minerals have similar crystal properties, including perfect cleavage which yields surfaces of rhombic outline. It is this cleavage that produces the bright reflections of light and gives life to the crystalline marbles.

The impurities in marbles take the form usually of scattered grains or crystals of the same order of magnitude as the calcite particles. In bedded limestones, on the other hand, they are distributed more or less evenly through the mass and consist of finely divided clayey and siliceous materials — the mechanical sediment formed during the deposition of the dissolved carbonates. The clay and silica form new combinations in the process of metamorphism, the carbonates supplying the lime and magnesia that may be required for the secondary minerals. Among the common foreign ingredients are muscovite, diopside and tremolite, but a great number of other silicates may occur. Any fine carbon is converted into scaly graphite. Some of the silica may remain as quartz. The iron minerals include hematite, magnetite and pyrite. The last-named is most harmful if present in any amount, since it decomposes readily in the atmosphere, producing a rusty stain which will spread over large areas.

TEXTURE

The texture of marbles varies greatly between examples from different localities. Some characteristic textures of New York marbles are illustrated in figures 15 and 17. The grain may be medium or fine, or may be uneven through the occurrence of different sizes of particles. The shape and arrangement of the particles also are quite variable and upon these features depend to a great extent the strength and weathering qualities of the stone. The Gouverneur monumental marble, composed predominately of calcite, has a very compact texture, with grains of uneven size and of angular to subrounded form. The particles frequently show dentate outlines by which they are firmly interlocked; the general appearance in fact is suggestive of the welded and dovetailed arrangement exhibited by some granites. The dolomite marbles of southeastern New York range from exceedingly coarse to very fine-grained varieties, but usually the grain in any one sample is fairly even. Some have a compact and firmly knit texture and then are strong durable stones; others are made up of rounded, smooth particles which simply adhere without interlockment. The latter kind are less durable.

WEATHERING QUALITIES

Marbles are much more subject to solvent action when exposed to the weather than the silicate rocks, and the effects of solution upon most marbles exceed those of mechanical agencies in promoting decay. Pure water, however, has little solvent power upon either calcite or dolomite; the action of atmospheric moisture depends upon the small amounts of acid constituents which are absorbed from the air. All rain water contains carbonic acid, and in cities where the consumption of soft coal is large it carries also more or less sulphuric acid formed by the combustion of the sulphide impurities in the coal. It may be expected, therefore, that the same marble will weather more rapidly in a humid climate than in a dry one. Fog and mist have an accentuated effect as they absorb relatively large proportions of the acids and enable the moisture to penetrate deeply into the stone.

A dolomite marble, under the same conditions and of equal quality in regard to textural characters, should prove more resistent to ordinary weathering agencies than a calcite marble. The fact is, however, that many dolomites succumb rather rapidly on exposure to the weather, as is shown in some examples that have been employed for building purposes in the East. Decay in these cases may be attributed mainly to the possession of an open weakly bonded texture which facilitates the penetration of moisture and attack by frost.

The dolomite marbles of southeastern New York include examples of exceptionally good building materials which have withstood well the severe tests of our climate and also others that have decayed rather rapidly under the same conditions. Smock[1] has given particulars of the relative durability of different marbles used in New York City, and states that some of the dolomites have a durability compared with that of the best sandstones. The old United States assay office in Wall street was built in 1823 of Tuckahoe marble; though yellow from age, the surface remained smooth and the edges sharp, whereas the Italian marbles used in the caps of the columns were much weathered. An example of rapid decay is found in the State Hall in Albany which was built between 1835

[1] Building Stone in New York. N. Y. State Museum Bul. 10, 1890, p. 292–94.

and 1842 of dolomitic marble from Ossining. The outer walls are roughened by pitting and scaling, and the cornices, lintels and columns are so much disintegrated by solution and frost as to present a very bad appearance. The stone is coarse and mealy in texture, ill suited for building purposes.

The composition of a marble, so far as relates to the relative percentages of calcium and magnesium, probably has a very subordinate influence upon weathering qualities. Much more important is the texture, and this is a feature that varies greatly with each particular quarry. The size of grain is not necessarily an indication one way or the other; though the coarse stones may possess larger and more continuous pores, their grains present relatively smaller surfaces to the attack of solvents than do the fine-grained sorts. The main elements determining the weathering qualities are the degree of compactness and the coherence between the grains. These can be ascertained by physical tests for porosity and tensile strength, and by study of thin sections under the microscope.

The presence of silicates in large crystals is detrimental to marble used for outside work, since there is not the same coherence between the crystals of silicates and those of the carbonates as between the carbonates alone, and consequently moisture gains access along their boundaries. Sulphides are still more obnoxious, not only producing iron stains, but also causing decomposition and pitting of the surface through the action of the sulphuric acid which is always formed by their oxidation.

Dale[1] has made some interesting observations on the effects of the New England climate upon marble monuments and tombstones and states that white marbles after exposure for 75 or 100 years have so far weathered as to indicate the complete effacement of the lettering within 300 years of the date of cutting.

Smock[2] gives as a quotation, the following notes in regard to the durability of the Gouverneur marble:

The Gouverneur marble was employed at least fifty years ago for gravestones, and in the Riverside Cemetery, at Gouverneur, these old gravestones, bearing the dates from 1812 onward, can now be seen. As compared with the white marble headstones from Vermont it is more durable; and there is not so luxuriant a growth of moss and lichen as on the latter stone, but in the case of the older

[1] The Commercial Marbles of Western Vermont. U. S. Geol. Survey Bul. 521, 1912, p. 38.

[2] Building Stone in New York. N. Y. State Museum Bul. 10, 1890, p. 237.

Gouverneur stone some signs of decay and disintegration, particularly on the tops, are noticeable, and small pieces can be chipped off with a knife blade. The durability of the stone for building purposes has been tested in some of the older structures in Gouverneur.

PHYSICAL PROPERTIES

Marble is heavier than granite and has a specific gravity ranging from about 2.70 in the case of calcite varieties to 2.88 for dolomites. These figures correspond to weights for each cubic foot of from 168 to 180 pounds. The South Dover white marble, a nearly pure dolomite, has a specific gravity of 2.86 and a weight of 178.5 pounds; the Gouverneur slightly magnesian blue marble possesses a specific gravity of 2.74 and a weight of 171 pounds for each cubic foot.

The compressive strength of marble varies within rather wide limits according to the textural features. Merrill[1] credits the Pleasantville coarse dolomite with the very high crushing strength of 22,383 pounds a square inch. The Tuckahoe marble, according to the same authority, gave a test of 13,076 pounds. Both figures refer to the strength when tested across the bed. Three samples of marble from the quarries of the South Dover Marble Co. showed a minimum compressive strength of 17,401 pounds and a maximum of 20,882 pounds.[2] These results compare well with those obtained from the best building marbles of other districts.

The Gouverneur marble, represented by a sample from the quarries of the St Lawrence Marble Co., showed a strength under compression of 12,692 pounds a square inch.[3]

Tests of transverse and tensile strength are rarely made, though they afford useful data in estimating the coherence and durability of marble.

GEOLOGY OF THE NEW YORK MARBLES

The metamorphic phanerocrystalline limestones, which include all marbles in the true sense, as already explained, occur only in regions where the rock formations have been squeezed, folded and upraised into mountains. Originally they were horizontally bedded, common limestones accumulated on the floors of the ancient seas by the slow aggregation of the shells of organisms that lived in these waters and in part perhaps by direct chemical precipitation

[1] Stones for Building and Decoration. New York, 1897, p. 461.
[2] Twentieth Annual Rep't U. S. Geol. Survey, pt 6, cont'd. 1899, p. 422.
[3] *Op. cit.*, p. 423.

of lime carbonate from solution. The formation of limestone by similar methods is going on today along the sea coast, as exemplified by the shell beds, coral reefs and calcareous muds which are widely distributed and which require only consolidation from the weight of overlying strata and uplift from the sea to convert them into limestones similar to those exposed in the early Paleozoic formations of New York State. The deposition of lime carbonate in quantity also takes place in fresh waters; the beds of marl found in many swamps and lake basins of this section are the result of precipitation of lime which has been brought in by tributary streams and springs, the lime being thrown out of solution sooner or later by evaporation of the waters or through the agency of plant growth. There are many thousands of acres of these surface marls in the central and western parts of the State.

The conversion of common limestone into marble requires great pressure, which in nature is developed through those crustal movements that lead to the formation of folded mountains; under the stress thus exerted, accompanied by heat and probably in the presence of moisture, the lime carbonate behaves like a mobile or plastic substance and is able to assume its proper crystal character, that of calcite. Each particle becomes a complete crystal, with the characteristic cleavage, optical properties and other features of calcite, though owing to the space limitations it can not assume the outward regularity of form which belongs to calcite when free to expand in all directions. The change, or metamorphism, is accompanied also by a rearrangement and crystallization of the impurities, as has already been noted.

There are two areas in New York where crustal movements have taken place on a great scale during past geological ages. The Adirondacks in the north are a part of the old Laurentian highland which was uplifted in early Precambric time and subjected to great vicissitudes of compressive folding, faulting and invasions by igneous rocks before the regular stratified formations began to be deposited. In the southeast is the Highlands-Taconic region, of which the Highlands proper represent a part of the old Appalachian highland of Precambric age, and the Taconic a later uplift that came at the close of the Ordovicic period.

THE ADIRONDACK SECTION

The crystalline limestones of the Adirondacks appear in belts, elongated in a general northeast-southwest direction parallel to the structural trend, and in smaller patches of variable shape and extent which have a very unequal distribution. They are rather abundantly represented on the eastern side in Essex and Warren counties, but mainly as scattered areas that cover a few square miles each at most. On the north in Clinton and Franklin counties are a few outcrops, and these unimportant; and the same may be said of the Southern Adirondacks included within Saratoga, Fulton, Herkimer and Lewis counties. The principal development of the limestones is on the northwest, in St Lawrence and Jefferson counties, outside the rugged mountain section but within the Precambric crystalline formations which here extend outward across the St Lawrence lowland and connect with the main Canadian expanse of the rocks. Four considerable belts of limestones, besides numerous smaller lenses and patches, exist in this section as may be seen by consulting the St Lawrence sheet of the State geologic map. Detailed information as to their extent and general features has been given by C. H. Smyth.[1] The most important exposure, areally and economically, has a length northeast and southwest of about 35 miles, extending from the town of Canton, St Lawrence county, to near Antwerp village in Jefferson county, with a width of from 1 to 7 or 8 miles and an area of 175 square miles. A parallel belt occurs a few miles northwest, about midway between its border and the St Lawrence river, and has a length of 15 miles, lying in the towns of Macomb, Hammond and Rossie, St Lawrence county, and Theresa, Jefferson county. Southwest of the main area is the Edwards-Fowler belt of St Lawrence county, notable for its talc deposits. The fourth belt lies farther southeast across the St Lawrence-Lewis county boundary, being partly in the town of Pitcairn of the former county and partly in the town of Diana of the latter. It is about 20 miles long and perhaps 2 or 3 miles wide as a maximum.

The belts are not wholly constituted of carbonate rocks, but include more or less quartzite, schist and gneiss which have the appearance of being interbedded with the limestones. Altogether the different formations represent the metamorphosed and deeply eroded remnants of what once must have been an extensive and varied series of sediments. The series included sandstones now changed to quartzites, arkose which has become quartzose gneisses,

[1] See especially, Report on the Crystalline Rocks of St Lawrence County, N. Y. State Museum Annual Rep't 49, v. 2, 1898, p. 481-90.

shales now altered to mica schists, argillaceous limestones that have become basic gneisses and amphibolites, as well as pure carbonate materials that are now marbles. The sediments at one time, no doubt, spread over the whole Adirondack region, and the present irregular and patchy distribution is the result of extensive erosion upon the formations which at different times were also invaded, broken up and to some extent absorbed by the great igneous masses which came up from below.

The metamorphosed sediments exhibit very similar features and relationships wherever found in the Adirondacks, so that they are regarded as members of a single geologic series, which is called the Grenville series from their analogy with the Canadian formations that bear that name. Little is known as to their time-relations beyond the fact that they antedate all the other Adirondack rocks, and consequently must have been laid down very early in the Precambric period. Subsequent to their deposition, but before the opening of Cambric time, there was a long era characterized by intervals of great igneous activity in which granite, anorthosite, syenite, gabbro and finally diabase were erupted. None of the members of the Grenville carries recognizable fossil remains, though the abundance of graphite in some of the strata, particularly the quartzites, leads to the inference that life existed at the time.

In most of the belts the limestones and the accompanying schists, quartzites and gneisses are tilted and present their upturned broken edges at the surface. The angle of inclination is usually high, dips of less than 30° being exceptional, whereas a nearly vertical attitude is quite common. The strike is nearly always between the north and easterly compass points, in most cases nearly northeast, but is subject to local variations. The beds over large areas may maintain monoclinal arrangement, with the inclination in the same direction; this is the common condition in fact, as few instances have come to notice where the dips of adjacent belts are in opposite directions. The general high inclination and the presence of minor folds seem to indicate, however, that the beds are not simply tilted up by a great monoclinal flexure, but that they have a much more complicated structure through the presence of anticlinal and synclinal folds strongly compressed. The actual relations that exist in any of the belts can not be stated at the present time, and it is still uncertain just what the order of the sedimentary succession may be.

The St Lawrence county belts are much broken by irruptive masses, of mainly granitic nature. These rocks have a massive to gneissoid appearance, but lack the schistosity of the Grenville gneisses, are prevailing reddish or gray in color and belong mostly to the biotite and hornblende varieties of granite. They form bosses of some size and also sills and dikes, while small offshoots cut through the sedimentary gneisses in a network of interlacing veins. They exert noticeable contact effects upon the limestones which in their vicinity may contain such minerals as tourmaline, vesuvianite pyroxene, tremolite, fluorite etc., often well crystallized.

THE GOUVERNEUR MARBLE

The crystalline limestone in the area about Gouverneur has furnished most of the marble that has been quarried in the Adirondack region. The area is a part of the belt which extends from the town of Canton, St Lawrence county, to near Antwerp, in Jefferson county, and which is traversed for much of the distance by the R. W. & O. branch of the New York Central Railroad.

The limestone in general is medium to coarse crystalline and white or light gray in color, but sometimes a dark blue as in one or two of the quarries. It is a calcite limestone, with a varying but generally small percentage of magnesia. The carbonates amount to about 95 per cent of the whole mass, of which nearly 90 per cent is calcium carbonate. Rarely the magnesia assumes sufficient importance to characterize the rock as a dolomite. The change from a calcite-limestone to dolomite takes place abruptly, but whether it reflects an original variation in the conditions of deposition or is due to secondary processes after the strata were laid down, is not clear. In the former case it would be expected to find the variation related to the bedded structure, but such relation can not be established. The occurrence of dolomite is quite local and unimportant as compared to the great body of limestone. On the other hand, the limestone shows well-marked zones or bands parallel to the bedding in which quartz is abundant and which seems to be the result of impurities included when the rock was being deposited.

The following analyses illustrate the chemical composition of the Gouverneur marbles. No. 1 is based on a sample from the Extra Dark quarry of the St Lawrence Marble Quarries; no. 2, quarry of the Gouverneur Marble Co; no. 3, Rylestone quarry; and no. 4, Northern New York quarry. No. 5 represents the dolomitic marble, formerly worked by the White Crystal Marble Co. Nos. 1, 2 and 3 are by R. W. Jones of the State Museum.

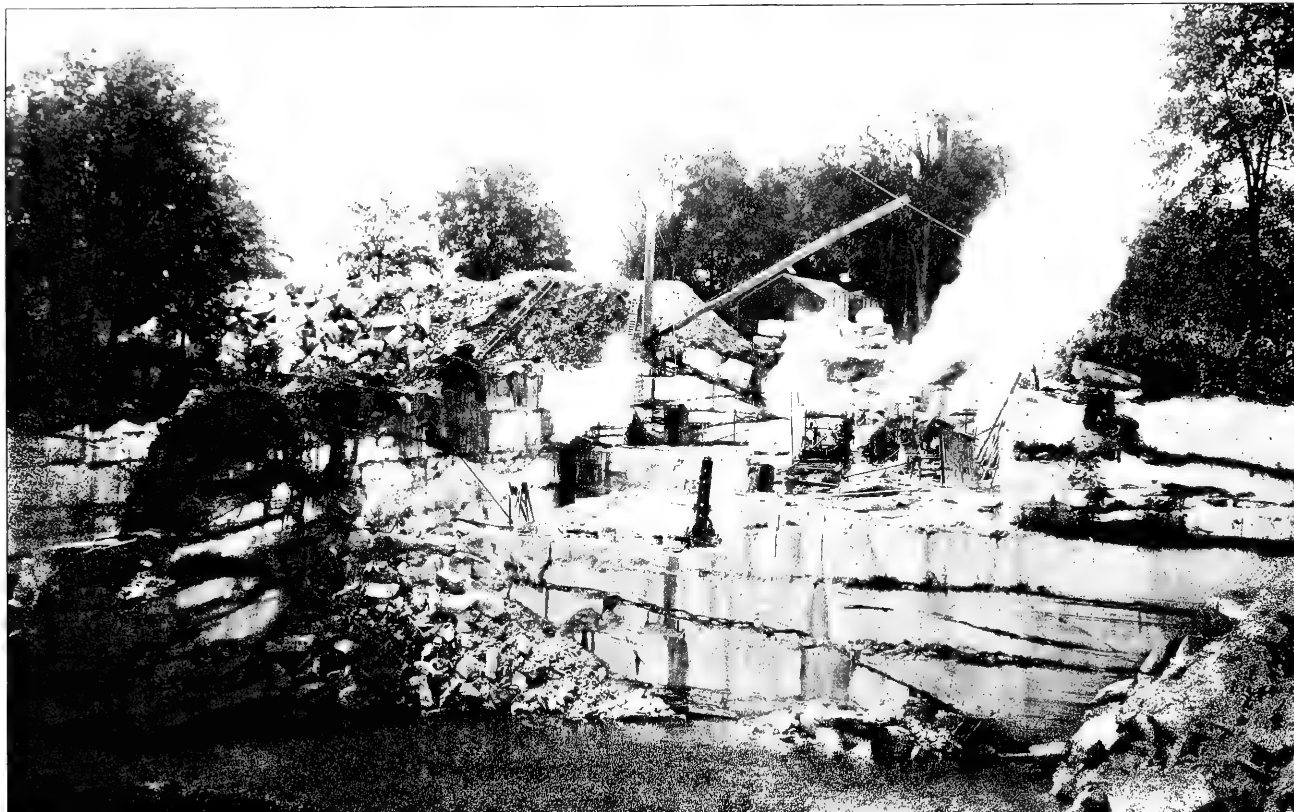
	1	2	3	4	5
Insol.	3.55	1.26	1.01	......	......
SiO_2	......	......	......	1.58	.28
Al_2O_3	.13	.65	.23	.79	.10
Fe_2O_3	.08	.29	.63		
MgO	......	......	......	3.49	20.64
$MgCO_3$	6.40	7.50	6.85	......	......
CaO	......	......	......	51.45	31.45
$CaCO_3$	87.06	87.47	88.94	......	......
H_2O	1.68	1.46	1.74	......	......
CO_2	......	......	......	42.56	47.38
S	.05	.02	.04	.03	.06

The Gouverneur marble is quarried from a small area southwest of that town. The quarries, with few exceptions, lie along a narrow belt which extends for a little over a mile in a northeast-southwest direction. They lie on the outcrop of the "vein" or bed which dips northwest at an angle ranging from 15° to 30° on the northeast end to 80° or 90° in the southwesterly quarries. The vein has a pitch that is toward the southwest at an angle of 20° or 25°. There is some suggestion in the field relations that the marble occurs along an overturned pitching fold.

In color and texture the marble shows variety, though the differences in composition are not especially prominent. It is a mottled white and grayish blue, or light and dark blue, running in places to an almost solid dark blue, which is the color most sought for. In the lighter mottled sorts the grain is moderately coarse and somewhat uneven, with the lighter and darker calcite segregated more or less into separate areas. The individual calcite particles mostly have a diameter from 1 to 2 mm. In the dark-blue marble, the grain is much finer, the calcite averaging only a fraction of a millimeter. The bluish color seems to be traceable to the presence of graphitic carbon in very small submicroscopic particles. Free carbon was detected by R. W. Jones in the analyses already given, but in too small amount to be separately weighed. That the variation of color conforms more or less closely to the bedding is evident from a study of the relations revealed in the different quarries. The lighter colors are found in the overlying beds of the northwestern section, and the fine-grained dark marble is from the structurally lower beds on the southeast. This feature has been confirmed as well by the results of core-drilling.

The marble is susceptible of high polish and has a luster and texture that resemble some gray granites. It is well adapted for monumental work and the better grades are used mainly for that

Plate 26



Extra dark quarry of the St Lawrence Marble Company. At left a vertical trap dike is seen, forming a wall between the two openings.

purpose. Its weathering qualities are attested by nearly a century of use as monumental and building stone. For building stone it has found considerable sale in the large towns and cities of New York and adjoining states, especially for public structures, churches

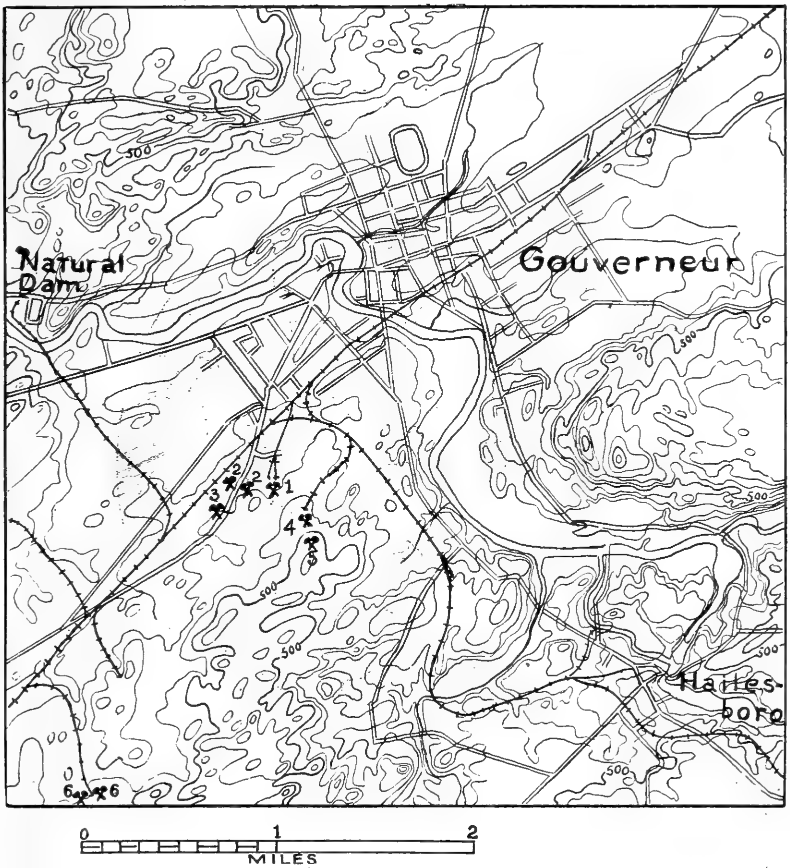


Fig. 14 Map of marble district near Gouverneur. 1 is Gouverneur; 2, St Lawrence; 3, Sullivan; 4, Callahan; 5, Extra Dark; 6, Northern New York quarries

and fine residences. In rock face, as used for building stone, the marble has a medium gray color, whereas the cut or patent hammered surface of trimmings shows much lighter. The selling prices vary with the color and uniformity.

Determinations of the specific gravity and absorption of the

Gouverneur marble gave the following results: specific gravity, 2.74; corresponding to a weight of 171 pounds to the cubic foot; ratio of absorption .111 per cent; pore space, .305 per cent.

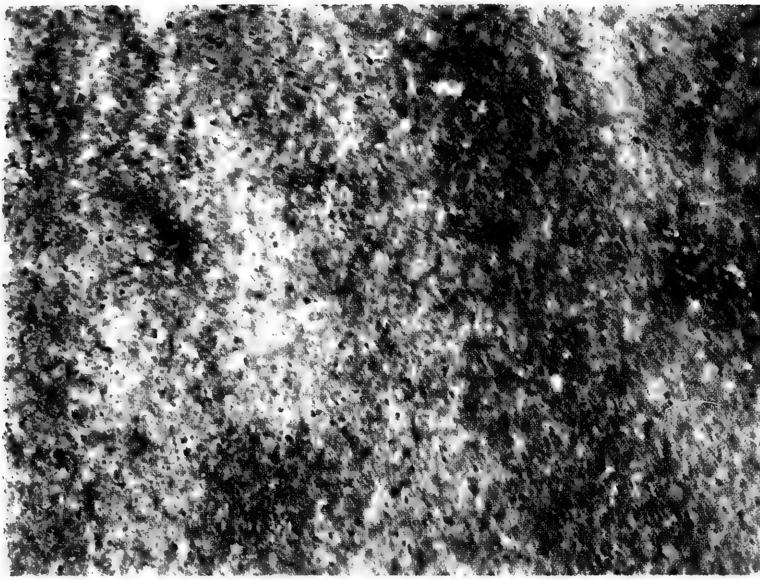
The St Lawrence Company's quarries

The quarries of this company include two openings near the mill and railroad track, a little more than a mile southwest of Gouverneur, and a third lying to the east on a separate vein. The latter, known as the Extra Dark quarry, alone was in operation

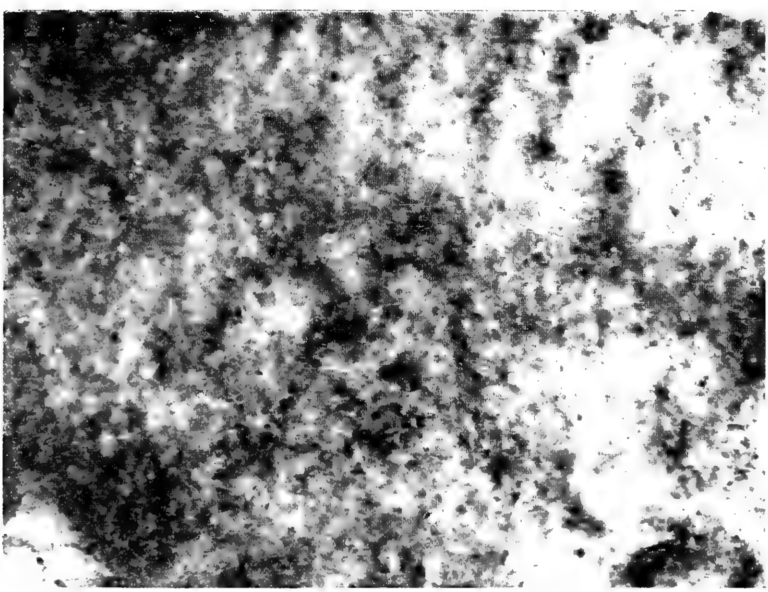
Fig. 15 Gouverneur marble in thin section, showing the irregular boundaries between the particles and firmly interlocked texture. Enlarged 25 diameters

at the time of the writer's visit in the fall of 1912. It is an opening 125 feet long, 80 feet wide and 20 to 30 feet deep. At the surface the marble is of medium bluish color somewhat mottled with white, but becomes dark blue below, which is the grade particularly sought, as the other quarries supply lighter stock. The beds dip northwest 30° and pitch southwest 25°. Two vertical joint systems running N. 30° W. and N. 65° E. are in evidence. As shown in the accompanying illustration, the quarry is crossed by a vertical trap dike which is left standing as a wall; the dike

Plate 27



Dark gray marble. Gouverneur



Mottled gray marble. Gouverneur

follows the northeasterly jointing and is from 2 to 3 feet thick, consisting of a serpentinous groundmass with lath-shaped feldspars.

The two openings near the mill, known as the St Lawrence quarries, are vertical rock cuts with an area of about 20,000 square feet each and a depth of 80 feet in the northerly quarry and 40 feet in the southerly one. They have supplied large quantities of building marble, of which examples are seen in the First Presbyterian church, Gouverneur; Grace church, Watertown; Jay Gould Memorial, Roxbury; Third Presbyterian church, Rochester; and in many other structures. For building purposes it is mostly used as rock face ashlar which has a bright gray color. The monumental stock is mainly the selected darker quality that is sold under the name "St Lawrence" but includes some lighter stone called "Adirondack." The beds here dip about 20° to the northwest. They have been penetrated to a depth of 400 feet in a drill hole near the cutting works.

The quarry equipment includes six channeling machines, two gadders and three derricks. The mill has sixteen gangs of saws, besides rubbing beds, lathes, and polishing machines. Electric power is used, supplied by the Hailesboro water power plant.

A chemical analysis of the marble from Extra Dark quarry is found on page 186.

The company states that the marble has a specific gravity of 2.76, corresponding to a weight of 172 pounds to the cubic foot. The ratio of absorption is .160.

Gouverneur Marble Company's quarries

The Gouverneur Marble Company owns quarries in the northeastern section of the marble belt, adjoining the property of the St Lawrence company. The principal one is a cut about 250 feet long and nearly as wide, with a depth of about 50 feet. A new opening 125 feet long and 50 feet wide has been made just southeast of the large quarry with which it will eventually be connected. The bedding here dips very low to the northwest. The jointing is in two systems, N. 40° W. and N. 50° E. which with the floor seams divide the marble into rectangular blocks. A test hole in the new quarry penetrated the marble to a depth of 95 feet.

The product runs mostly to the medium and light varieties, but the new opening shows considerable darker marble from the underlying beds. The grain is moderately coarse, with a grain diameter of 2 to 3 mm. There is a little phlogopite in small but visible scales distributed through the carbonates. The marble from these quarries is often beautifully mottled and such material is used in polished work. As a building stone it has been employed in many large structures, notably in the Sacred Heart and St Anthony's churches in Syracuse, and the high school in Schenectady.

The mill, situated near the quarries, is equipped with eleven gangs of saws.

Northern New York Marble Company's quarries

The property of the Northern New York Marble Co. lies in the southwestern section of the Gouverneur district separated from the other quarries by a considerable stretch of undeveloped ground. Its position is east of the extension of the line connecting the more northerly openings, which indicates that it is on a lower vein structurally than the others. Otherwise there must be a fault or a wide deviation of the strike in the interval. There is some similarity in the character of the marble with that of the Extra Dark quarry of the St Lawrence company, which lies on the footwall side of the main belt. The strike of the beds here is N. 70°–80° E. and the dip 80° north.

The main quarry measures 140 feet by 75 feet at the surface and is over 200 feet in depth. It has been abandoned on account of the depth. A second quarry 100 feet south has furnished the recent output; it is an opening 120 feet long and with a depth of from 40 to 65 feet. In 1912 the development of a third quarry was begun, situated to the west of the latter, with which it will eventually connect. The quarries are equipped with two derricks and have the usual oufit of channelers and gadders.

The marble has a dark blue color for the most part, averaging much darker than the usual Gouverneur product, and is also finer textured. The grain diameter ranges from 0.5 to 1 mm in the darkest samples. As shown by the analysis on page 186, it is a high grade magnesian limestone with only about 2 per cent impurities. The product is sold under the name of "Northern New York" and is graded according to the presence or absence of lighter veins or clouds in the dark blue ground. It is mainly in demand for monumental work. A good proportion of the lighter quality is hammer-faced, not polished, a finish which gives the appearance of tooled granite.

Plate 28

Shipping yard and mill of St Lawrence Marble Company

In the quarry walls a few knots from silicate inclusions are in evidence; they rarely exceed a foot in diameter. Open joints and fissures occur in the upper 15 feet where the marble is more or less discolored and disintegrated, but below the stone is fresh, uniform and little broken by joints. The surface has been polished and in places is deeply grooved by glacial ice.

The Rylestone quarry

The Rylestone quarry, worked up to a short time ago, lies west of the main belt, a mile or more, on the side of a low ridge. It was not operated in 1912 when inspected by the writer. The marble is bluish gray, with an equal mixture of white and blue calcite. The grain is fine to medium, the particles ranging from 1 to 3 mm in diameter. The texture is rather uneven. Apparently there has been considerable loss in quarrying from the presence of vugs, which are apt to occur in the midst of an otherwise sound block. These vugs take the form of small round cavities and of seams a foot or more long and are lined with crystallized calcite, marcasite and brown tourmaline.

The quarry face extends along the base of the hill for 100 feet and is 50 feet high. In the last operations the stone was broken down by blasting, which has left much waste. A mill equipped with eight gangs of saws is situated on the property.

Other quarries near Gouverneur

The John J. Sullivan quarry, now closed, is situated 500 feet west of the St Lawrence quarries. The pit is about 100 feet long and 50 feet wide. The marble exposed on the edge near the surface is coarse-banded, white and blue, of rather light appearance. Some of the beds show disseminated scales of mica, tremolite crystals and other silicates. The quarry equipment has been dismantled and the pit allowed to fill with water.

The Callahan quarry is a small opening near the Extra Dark quarry of the St Lawrence company. The marble is of medium, bluish gray color and moderately coarse texture. The quarry was last worked five or six years ago.

The D. J. Whitney quarries lie near those of the Northern New York Marble Co. They have yielded considerable quantities of medium to dark-colored stock, used for monumental work. They have been inoperative for several years.

The White Crystal Marble Co. opened a quarry about ten years ago in the vicinity of Gouverneur for the supply of building material. The stone has a coarse texture and is pure white. The analysis on page 186 shows it to be a dolomite. Physical tests made at the Watertown Arsenal (Mass.) indicated the crushing strength of one sample to be 25,250 pounds to the square inch; of another sample 23,070 pounds to the square inch. This is well above the average of most marbles, and the stone is probably equal to any practical requirement in regard to strength. The quarry is owned by C. A. Lux of Syracuse.

Furnace flux is shipped by Corrigan, McKinney & Co. from a quarry situated 2½ miles north of Gouverneur, the output going to the company's furnace at Charlotte.

FOWLER, ST LAWRENCE COUNTY

A white, coarse dolomitic marble occurs in the town of Fowler as a part of the belt of crystalline limestones which inclose the talc beds of that section. An extensive exposure of the brilliant white stone is found on the Abbott farm just west of the hamlet of Little York. It has been worked to some extent by A. B. Scott, principally for shipment to makers of artificial stone. The marble is free of stain and can be obtained in large blocks. According to information supplied by Mr Scott, the stone shows 18 per cent magnesia (MgO) and about 8 per cent of foreign matter.

CANTON, ST LAWRENCE COUNTY

An active marble-quarrying industry was conducted a few years since in the northeastern section of the limestone belt, south of Canton and in some of the small outlying areas of limestone in that part of St Lawrence county. An account of some of the later operations has been given by W. N. Logan.[1]

The E. E. Stevens quarry is 1½ miles southwest of Canton village. The stone has a grayish color, with a close resemblance to gray marble on cut surfaces. The output in the years preceding 1902 was valued at $40,000 annually.

The Nickerson quarry is mentioned by Stevens as containing a light yellow marble with serpentine inclusions. It is on the Nickerson farm 2 miles south of Canton village.

White marble was produced at one time in the Clarkson quarry, near DeKalb Junction. The output in the last year of operations is placed by Logan at $15,000.

[1] 23d Report of the State Geologist, 1904, p. 118–19.

Plate 29

Gouverneur Marble Company's Quarry

The small area of crystalline limestone near Colton, south of Potsdam, has been developed in one or two places for marble. One quarry is situated on the Peter Fallon farm, about 2 miles east of Colton village, and another on the farm of J. C. Leary in the same vicinity.

HARRISVILLE, LEWIS COUNTY

Building and monumental marble has been quarried on a small scale in years past at Harrisville, Lewis county. The quarry is about 500 feet north of the railroad at the base of a low hill and consists of an opening 75 feet square. It is an indistinctly banded grayish marble, light in tone, and rather coarse, with a grain diameter of 1 to 3 mm. The banding apparently is a bedding feature, the darker bands containing a higher percentage of impurities than the lighter ones. The direction of the banding is northeast-southwest and the dip 40° northwest. The impurities, which consist of serpentine, pyroxene and some sulphides, would seem to be a drawback to the use of the stone for polished work. An analysis of an average sample made by R. W. Jones gave the following percentages:

SiO_2	1.64
Fe_2O_3	.04
$MgCO_3$	21.79
$CaCO_3$	76.17
	99.64

NATURAL BRIDGE, LEWIS COUNTY

Quarries have been opened in the crystalline limestones in the vicinity of Natural Bridge for the manufacture of lime. The limestones are coarse, dolomitic and as a rule not adapted for cut stone.

The New York Lime Co. has carried on operations for several years in a quarry at Sterlingbush, north of Natural Bridge, and also at the latter place and at Bonaparte Lake where the dolomites attain a degree of purity requisite for lime manufacture. The product is mainly sold to pulp manufacturers for use in the sulphite mills.

THE HIGHLANDS — TACONIC AREA

Crystalline limestones occur in many places in the Highlands region and in the bordering metamorphic area to the north and south. They are specially prominent on the east side of the Hudson where they underlie many of the north-south stream valleys of

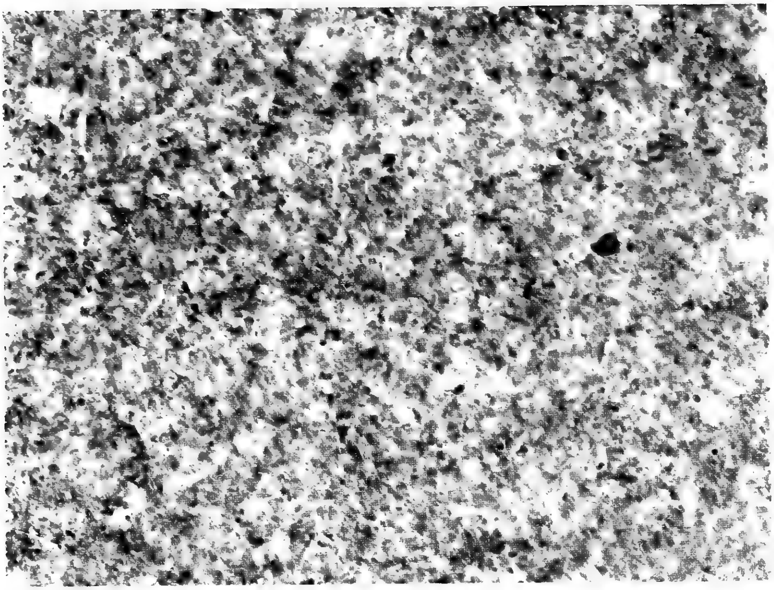
Westchester, Putnam and Dutchess counties, but also occur in Orange county as a continuation of the northern New Jersey belts. Those of a thoroughly crystalline character are associated with schists, quartzites and thin-bedded gneisses, forming a series of interfolded metamorphosed sediments that bear some resemblance in certain aspects to the Grenville series of the Adirondacks. Their stratigraphic position is doubtful; it would appear that they may represent more than one period of formation, as indicated by the varying degree of metamorphism which they have undergone.

In Westchester county the limestone is coarsely crystalline, white, and usually carries magnesia in proportions characteristic of dolomites, though in the very northern part of the county there are limestones with low magnesia. The name "Inwood" was first applied to the limestones by F. J. H. Merrill, who later advocated the view of the general equivalence of the limestones in this section with those of western New England and withdrew that name in favor of the prior term "Stockbridge" limestone. Merrill and other geologists have regarded the Westchester county limestones as a southerly extension of the belts that are found north of the Highlands where they are much less metamorphosed and are known to be of Cambro-Ordovicic age.

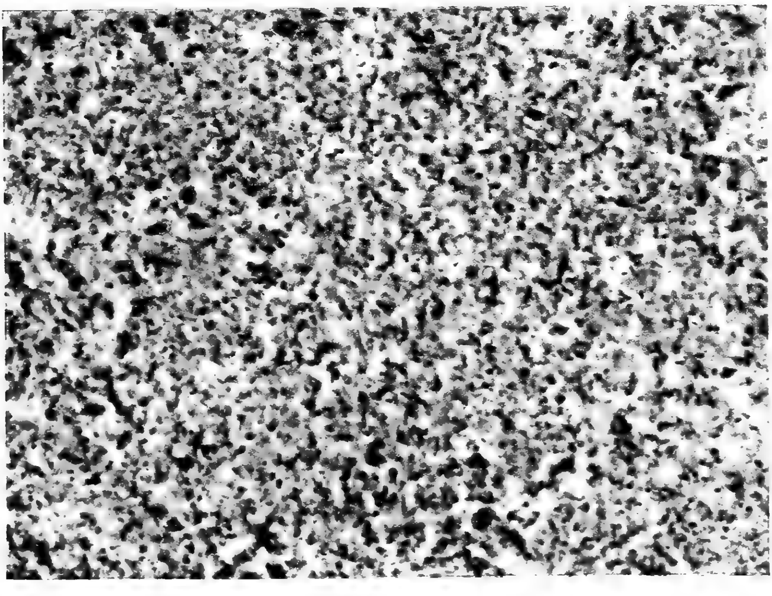
More recently Berkey has indicated the possibility of the existence of two main series of limestones. The Westchester county representatives, accompanied by the Lowerre quartzite and Manhattan schist, show no marked unconformity with the underlying gneisses, and are considered as Precambric. The second assemblage includes the less changed types of white and blue limestones, developed mainly to the north of the Highlands, which have been known as the Wappinger limestone and which are associated with the Poughquag quartzite and the Hudson River slates. These show a marked unconformity in contact with the gneiss formation. Small bands and lenses of impure limestone occur within the Highlands gneisses, and are probably the oldest of all, that is of Grenville age. The latter have little economic importance.

The crystalline limestones of southeastern New York are prevailingly high in magnesia, though there are some localities where they carry under 5 per cent. In the developed marble quarries the stone is usually a true dolomite. The proportion of lime carbonate ranges from 55 per cent as a lower limit to about 70 per cent, while the magnesium carbonate amounts to from 30 to 45 per cent. The siliceous impurities are usually low, not over 2 or 3 per cent of the

Plate 30



Dark gray marble. Gouverneur



Green marble (Ophicalcite). Moriah, Essex county

whole. They are due to inclusions of quartz, mica, tremolite, diopside and more rarely tourmaline.

The building marbles are found in the more massive, heavily bedded parts of the formations. They are predominantly white, either a uniform brilliant white, or white clouded or banded with blue. They are used both for exterior and interior work. Examples of their architectural employment may be seen in many large structures in New York City, especially among the buildings erected twenty or more years ago, as at that time the Westchester county stone enjoyed greater favor among architects than any other native marble.

In durability, the dolomitic marbles from southeastern New York show considerable variation, as has been remarked in the discussion of weathering qualities. Some of the stone is ill-adapted to building purposes on account of the fact that certain phases show a sugary, loosely bonded texture and decay rapidly when exposed to the elements. It is unfortunate that such stone should ever have been employed in buildings. On the other hand, the product of many of the quarries has proved, under the rather trying conditions of the eastern cities, to be an excellent architectural stone, equal in weathering qualities to any of the other marbles in common use. Rapid weathering apparently does not result from any peculiarities in the composition of the stone, but depends upon a lack of coherence and compactness whereby the mechanical influences of frost and temperature changes are enabled to destroy the bond. Normally, dolomite is harder and more resistent to the attack of solvents than calcium limestones.

DOVER PLAINS, DUTCHESS COUNTY

Marble for building and ornamental purposes was once quarried near Dover Plains. The ledges may be seen along the east side of Tenmile creek southeast of the town. One of them is now the site of an active quarry which is worked by the Dutchess County Lime Co. for the manufacture of lime. The stone is a fine but rather loosely grained dolomite, blue or white in color, and quite free of silicates. The dolomite grains are round and not firmly welded, so that they weather out readily when the stone is exposed to the atmosphere. The beds in this section strike about N. 10° E. and stand on edge or are inclined to the east at an angle of 80° to 85°. The color changes abruptly from white to blue across the strike, apparently with the different beds. With its low percentage of soluble matter (2 to 3 per cent), the stone is well adapted for making magnesian lime.

WINGDALE, DUTCHESS COUNTY

South Dover Marble Company's quarries

The South Dover Marble Co. has large marble quarries 2 miles in a direct line northeast of Wingdale station on the Harlem Rail-

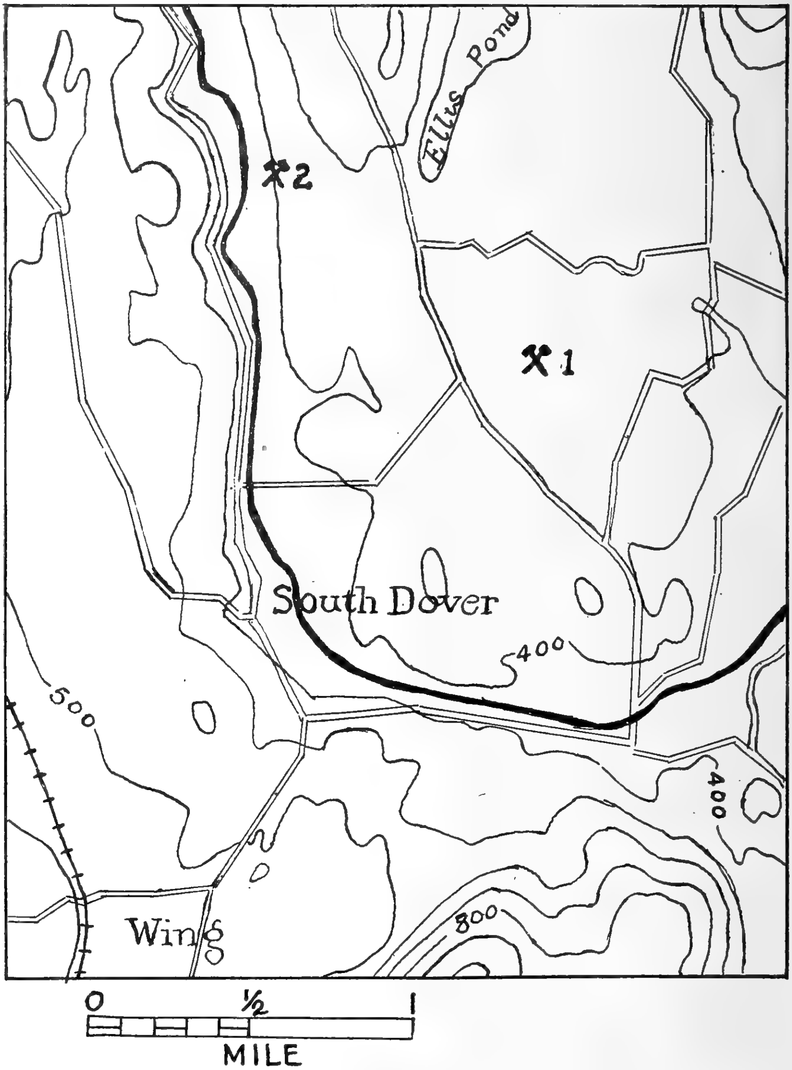
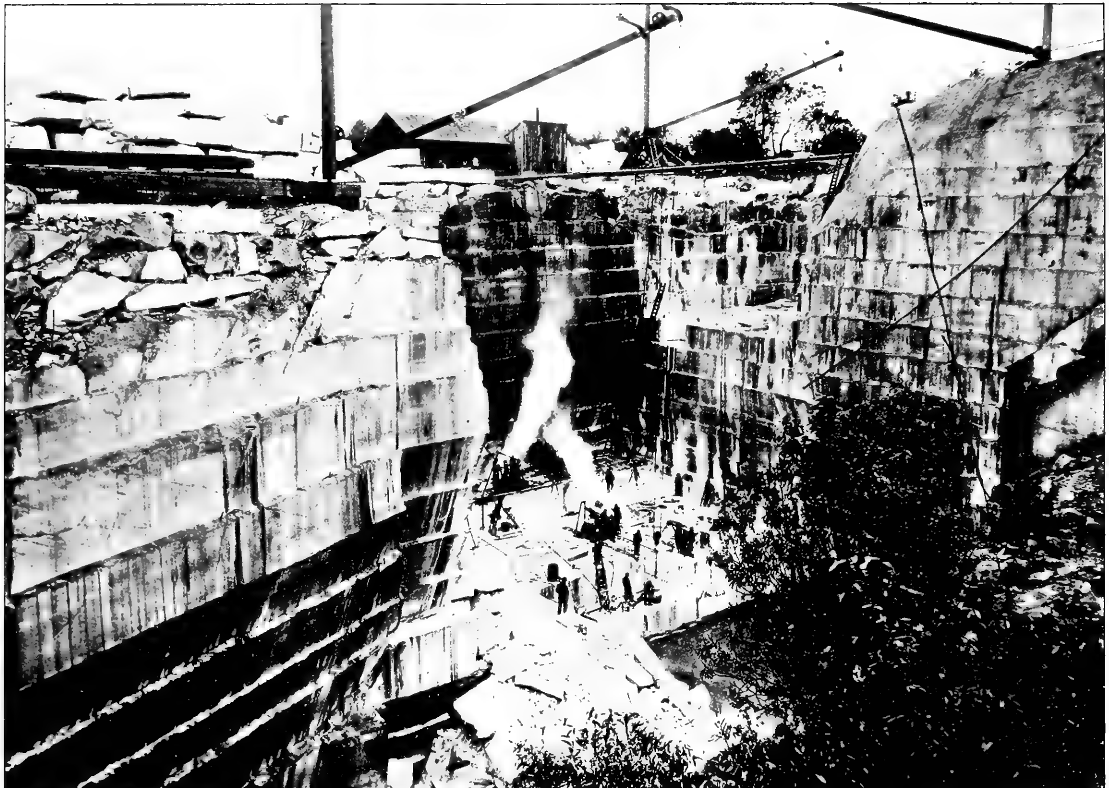


Fig. 16 Map of South Dover quarries. 1 is South Dover; 2, Dover White quarries

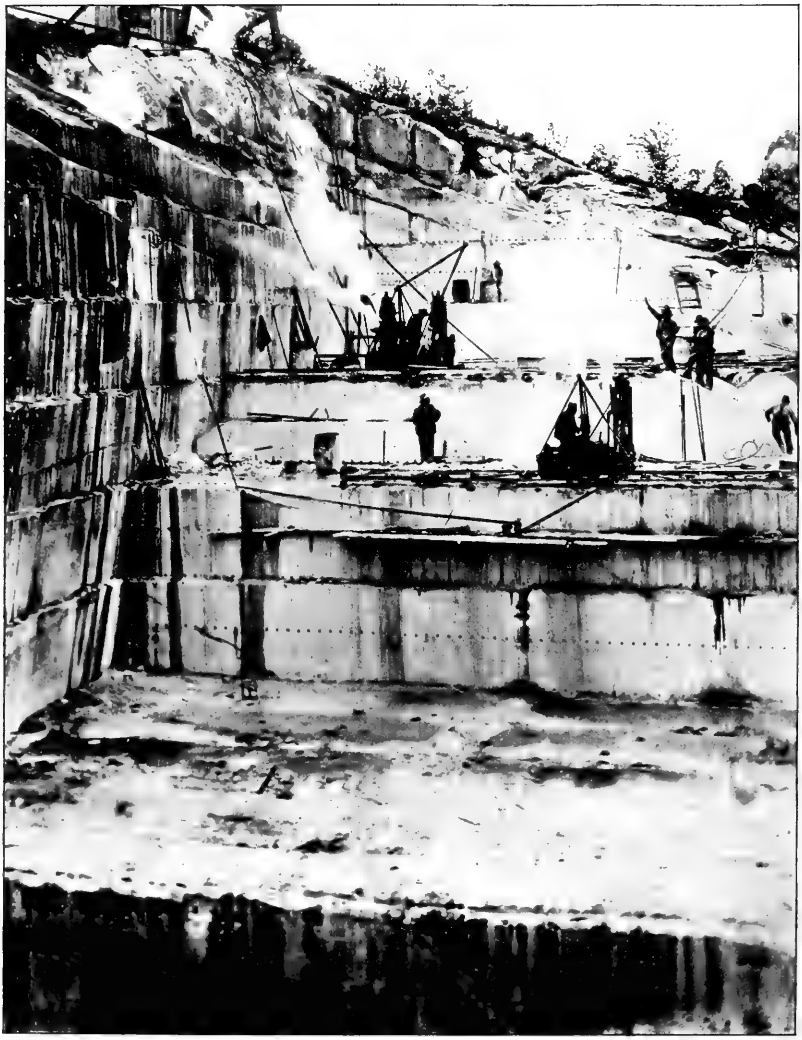
road. The belt of crystalline limestone in which lie the quarries stretches along the flanks of a broad gneiss ridge which extends

Plate 31



The main quarry of the South Dover Marble Company, Wingdale

Plate 32



Upper quarry of the South Dover Marble Company, Wingdale

north and south on the New York–Connecticut boundary. The surface is flat or slightly hilly in contrast with the rugged outcrop of the gneiss. The limestone maintains a nearly uniform course slightly east of north and shows usually an easterly inclination, but for short distances the dip may change to the west. Along with the limestone appears a white quartzite that may be seen a little to the west of the quarry openings.

The product of the quarries is a uniform white marble suited for building and interior work. The grain is fine; the particles average from .75 to 1 mm diameter and are prismatic or subrounded in form. In the exposed beds the marble appears very compact and, except for the upper few feet just below the soil, is neither stained nor weathered. Its appearance in thin section is shown in figure 17. Physical tests indicate a specific gravity of 2.86, ratio of absorption .144 per cent, and pore space .51 per cent. The weight is 178.5 pounds to the cubic foot. Strength tests made by Prof. Ira H. Woolson in the laboratories of the School of Mines, Columbia University, gave ultimate resistances to compression of 17,401 pounds to the square inch on one sample, 18,836 on another and 20,882 on a third, tested on the bed.[1] An analysis supplied by the company indicates that the lime and magnesia occur in the proportions of a true dolomite.

SiO_2	.70
Al_2O_3	.37
Fe_2O_3	.25
MgO	20.25
CaO	30.63
Na_2O	.12
K_2O	.46
Loss and undet.	.56
CO_2	46.66
	100.00

The company has two quarries, the one being on the east slope of a low ridge facing the gneiss ridge and the second a little farther up the slope and northwest of the first. The lower quarry has an extreme length of 250 feet, a width of 150 feet as a maximum and a depth of 135 feet. There are three derricks in place. The other opening is 150 feet long, 75 feet wide and about 60 feet deep. It has two derricks and an overhead cableway, the latter for carrying

[1] U. S. Geol. Surv. 20th Ann. Rep't, pt 3, p. 422.

the waste to the dump. Both openings extend downward vertically, both with the bedding, which dips easterly about 40° in the south quarry and westerly 50° to 60° in the north, the dip reversing within a distance of 100 feet. There are few open joints or fissures, though one rather conspicuous opening in the southern quarry extends to a depth of 50 feet. There are occasional bunches of silicates and a little pyrite appears on some of the joint surfaces.

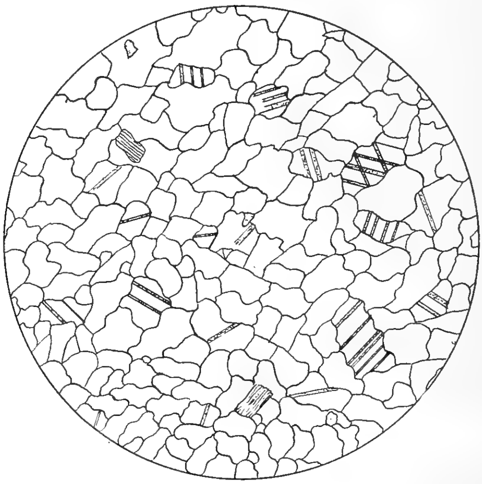


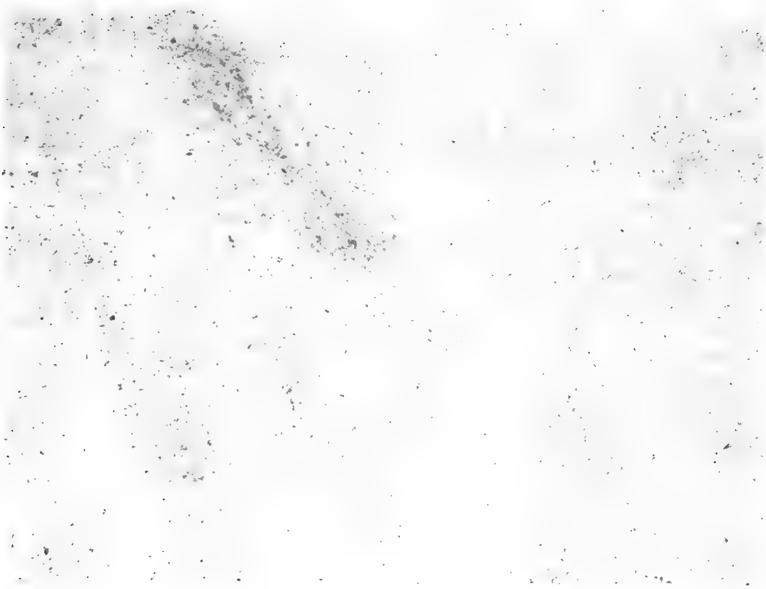
Fig. 17 South Dover marble in thin section. Enlarged 10 times

The South Dover Marble Co. has a cutting and polishing works at Wingdale station with which the quarries are connected by an electric tram. The product has been used in many large structures in New York and the eastern cities, and is one of the standard architectural materials of this county. Some of the important buildings in which it may be seen are the Tiffany Building, Blair Building, Stock Exchange (interior), Masonic Temple and Charles Building in New York, Essex County court house in New Jersey, Munsey Building and House of Representatives office building in Washington.

Dover White Marble Company's quarry

The quarry recently worked by the Dover White Marble Co. lies on the east bank of Tenmile creek 1½ miles northwest of the South Dover Company's quarry. It is a small side-hill opening in a white dolomitic marble which is streaked or banded with gray. The bands consist of quartz and sericitic layers, arranged parallel to the

Plate 33



Dover white marble. Wingdale, Dutchess county

Black marble. Glens Falls

bedding. They are somewhat wavy when seen in cross-section, as they have been subjected to powerful compression during the uplifting of the beds which stand nearly on end. The strike is about north and south and the dip 80° east. The bedding joints have been healed by flowage and crystallization of the carbonates, though still obscured in places as blind checks and seams. The marble has a fine grain with average diameters of less than .5 mm. The product has been employed mainly for veneer and wainscoting, for which purpose it is shown across the bedding so as to bring out the banding. The quarries were closed in 1912.

TURNER'S CORNERS, PUTNAM COUNTY

A gray marble was quarried at one time near Turner's Corners. The stone is rather coarse and in the outcrop shows a crumbly loose grain. It was employed in the dam at Sodus on the Croton water supply.

PEEKSKILL, WESTCHESTER COUNTY

A magnesian limestone of considerable purity and white to gray in color is found along Sprout Brook valley, north of Peekskill. It has been worked to some extent for lime, notably on the Frost place where there is a quarry and kiln, now idle. A sample of the stone selected to afford an average of the whole quarry face showed the following results, as reported to the writer by T. M. Williams (H. D. Gehret, analyst):

SiO_2	.70
Al_2O_3 / Fe_2O_3	1.35
$MgCO_3$	6.00
$CaCO_3$	91.40
P_2O_5	.03
H_2O	.25
	99.73

The crystalline limestone continues northward into Putnam county and outcrops in force on the Couch, Slater and Barrett farms, in some places possessing a uniform white color and even texture like the best marbles of this region. The stone differs from the latter, however, in it relatively small magnesia content. Another analysis of the stone from the Couch farm, by H. D. Gehret, showed:

SiO_2	.90
Al_2O_3 } Fe_2O_3 }	1.38
$MgCO_3$	10.00
$CaCO_3$	86.60
P_2O_5	.02
H_2O	.10
	99.00

OSSINING, WESTCHESTER COUNTY

The locality at Ossining has interest as affording structural marble for several buildings, including the State Hall at Albany. The quarries are situated in the yard of the State prison. The marble is a white or gray dolomite, rather crumbly in texture, and hence not well adapted for exterior work.

The Ossining Lime Co. has a flux and lime quarry south of the village near the railroad. The stone contains about 20 per cent magnesia, as shown by the following analysis:

SiO_2	.87
Al_2O_3	.57
Fe_2O_3	.25
MgO	19.95
CaO	31.40

WHITE PLAINS, WESTCHESTER COUNTY

A quarry about a mile north of White Plains and just west of the Harlem Railroad has been worked as a source of material for lime and crushed stone. It is known as the James O'Connell quarry. An analysis by Huntington gives the following components:[1]

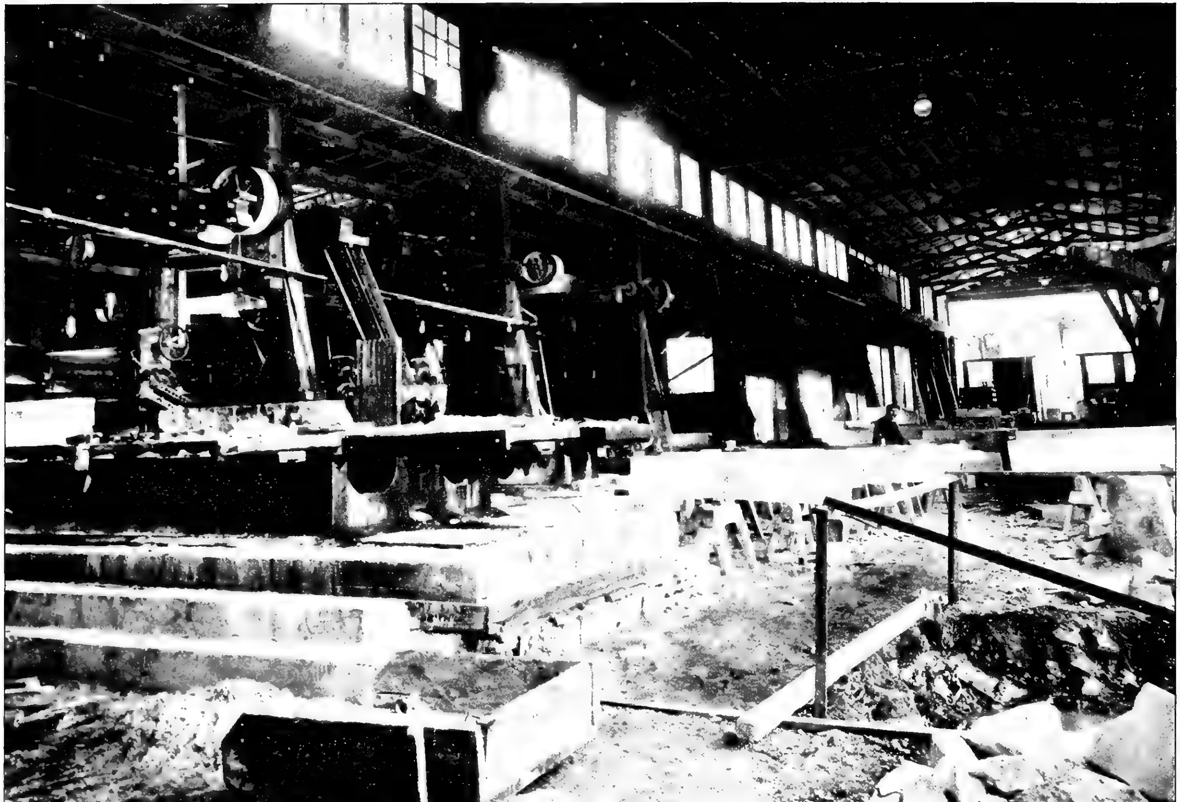
SiO_2	2.08
Al_2O_3 } Fe_2O_3 }	.56
$MgCO_3$	37.79
$CaCO_3$	58.72
	99.15

PLEASANTVILLE, WESTCHESTER COUNTY

A white dolomitic marble that is found near Pleasantville has supplied considerable building material for New York City and the

[1] Eckel. "The Quarry Industry in Southeastern New York." 20th Report N. Y. State Geologist, 1902, p. 172.

Plate 34



A part of the mill of the South Dover Marble Company at Wingdale

towns along the Hudson river. There are several quarries, now abandoned, of which those formerly worked by the Snowflake Marble Co. have been the principal sources of architectural marble. The beds of the best quality measure about 100 feet thick and stand in vertical position; they are pure white, with very little foreign matter. The grain is extremely coarse, so that on a fractured surface the cleavage planes of the dolomite appear as large rhombic mirrorlike faces. A specimen in the State Museum collections has an average grain diameter of 8-10 mm. The texture is close and well knit, the dry stone absorbing only .15 per cent of water, according to Smock. The specific gravity is 2.87 and the weight 179 pounds to the cubic foot. Determinations of crushing strength by General Gilmore gave a maximum of 24,825 and a minimum of 18,750 pounds to the square inch from six tests. The following analyses illustrate the chemical composition of the marble:

	1	2	3
SiO_2	2.31	.10	.29
Al_2O_3	.40	.07	.....
Fe_2O_3	.25	.11	.....
$MgCO_3$	36.80	45.04	43.11
$CaCO_3$	59.84	54.12	54.80
Total	99.60	99.44	.....

Analysis no. 1 is by H. Ries;[1] no. 2 by C. F. Chandler;[2] and no. 3 by F. A. Wilber.[3]

The stone is too coarse for sawed or polished work. Its architectural quality may be observed in St Patrick's Cathedral (lower walls) in New York and the Methodist Episcopal Church in Ossining.

TUCKAHOE, WESTCHESTER COUNTY

A very active quarry industry was centered a few years ago at Tuckahoe. There are several openings in a narrow belt of dolomitic marble which extends in a north-northeast direction and is inclosed by Fordham gneiss on the west and the Manhattan schist on the east. The marble beds range from 40 or 50 feet to 100 feet or more in width. Their outcrop is marked by a surface depression between the ridges of harder rocks.

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[1] N. Y. State Museum Bul. 44, 1901, p. 832.

[2] U. S. Geol. Surv. 20th Annual Rep't, pt VI, 1899, p. 42.

[3] N. Y. State Museum Bul. 10, 1890, table facing p. 358.

One of the leading quarries for architectural stone is that last operated by the Waverly Marble Co., which suspended work in 1908, and previously operated in succession by Norcross Bros., A. T. Stewart and by A. Maxwell. It is an open pit 600 feet long, 150 feet wide, and 75 feet deep. A large part of the excavation afforded material suitable for architectural use, which may be seen in some of the large structures in New York, Boston and other cities. Among the more recent buildings that have been erected from the marble are those of the New York and Metropolitan Life Companies in New York. It is a coarse, brilliant white dolomite, very hard and almost devoid of silicate impurities except for occasional mica scales. The texture is very close; the grains have rhombic and irregular sections and range in diameter from 1 to 5 mm. It is thoroughly massive in appearance.

Since the quarries have been closed some marble has been shipped from the stock piles and the waste also has been employed in the manufacture of artificial stone. The Emerson-Norris Co. of New York has a plant at the quarries for making all kinds of artificial building stone, for which the white marble serves as the basis.

The Tuckahoe or Young's quarry lies in the center of the developed section. It is a cut 600 feet long and 100 feet in maximum width. The stone resembles the product from the Waverly quarry but is somewhat coarser. The quarry has furnished material lately for crushed stone for use in white concrete. The Kapailo Manufacturing Co. pumped out the workings in 1912 and have carried on work in a small way.

The Masterton or New York quarry lies on the south end and consists of two openings. It was very actively worked in the sixties and seventies of the last century. Of late years it has supplied material for making lime and marble dust. A polished sample in the State Museum collections shows a coarse, white dolomite with brownish inclusions of tremolite more or less completely altered to talc. The stone contains lime and magnesia in the proportions of true dolomite. Its specific gravity is 2.87, equivalent to 178 pounds to the cubic foot. The dry material, according to Smock, absorbs 0.14 per cent water. The following chemical analyses are based on the material of this quarry, but exemplify the general character of Tuckahoe marble.

	1	2	3
SiO_2	.24	..	..
Al_2O_3	.19	..	..
Fe_2O_3	.21	.21	..

MgO	21.25	20.71	20.77
$MgCO_3$	.....	.....	43.62
CaO	30.16	[illegible]	30.63
$CaCO_3$	.....	.....	54.69
CO_2	47.3	46.66	.....
Insol.	.....	1.33	.91
..	99.35	99.59	.....

Analysis no. 1 is by W. F. Hillebrand; no. 2 by P. deP. Ricketts; no. 3 by F. A. Wilber.

NONMETAMORPHIC MARBLES

Several kinds of unmetamorphosed limestones that occur in the State have been used for ornamental stones and may be included with the marbles for purposes of description.

GLENS FALLS

The Paleozoic limestones at Glens Falls, which are exposed in cliffs on both sides of the Hudson river, contain at their base a thick-bedded, fine-grained black limestone of Black River age. The layer is about 12 feet thick. The overlying limestones and shaly layers belong to the lowermost Trenton beds and are known as the Glens Falls limestone. The thicker and finer limestones are quarried for lime, building stone and other purposes, while the black layer yields also a good black marble. When polished, the latter shows a dense uniform black surface, scarcely distinguishable in appearance from the best of the imported black marbles. It is hard and very fine in grain. Large quantities were quarried and cut at one time, but the demand has fallen off in recent years. The stone was used largely for floor tiling, for which it was well adapted on account of its good wearing qualities and permanency of color. It has been made also into mantels, wainscoting, table tops and other interior decorative work. The principal shipper of late years has been Finch, Pruyn & Co. who use the materials also for lime and crushed stone. Smock states that the black marble has a specific gravity of 2.718 and weighs 169.4 pounds to the cubic foot. G. P. Merrill gives crushing tests on limestone from Glens Falls which may refer to the black layer, although not so stated. The strength on the bed was 11,475 pounds and on the edge 10,750 pounds to the square inch.

WILLSBORO POINT, ESSEX COUNTY

A fine black limestone is found in the Chazy beds which underlie the long neck of land that projects into Lake Champlain from the

Essex county shore. The beds contain from 16 to 18 feet of workable limestone, well adapted for building material, mostly of a gray or bluish gray color. Examples of the architectural use of the limestone are to be seen in the Reformed Church on Swan street, Albany, the eastern foundations and subbasement of the State Capitol, in the Brooklyn Bridge piers and other structures. The black layers were employed for ornamental work. A polished specimen in the collections of the State Museum shows that the stone is somewhat coarser than the Glens Falls material, with visible particles of crystalline calcite, but the color is rather a bluish black than a dense jet black. The quarries have not been worked in recent years.

PLATTSBURG

Quarries at Bluff Point, south of Plattsburg, supply an excellent "shell" marble which is found in the Chazy formation. The stone consists of fossil fragments, mostly rounded red and pink particles which have been derived from crinoid stems, with dark fragments of brachiopods in less abundance. The red particles measure from 2 to 5 mm in diameter. The fossils are inclosed in a gray groundmass that shows many glistening calcite cleavages, the texture being partly crystalline, thus approaching that of a true marble. As a consequence of this texture the stone takes a good polish, and the varicolored fossils lend an ornamental effect which is quite attractive. It has been sold as "Lepanto" marble, mainly for use in interior decoration. The quarries are now worked by the Vermont Marble Co. and the product is shipped to that company's works for cutting and polishing. In character the stone is a high-grade calcium limestone, containing 95 or 96 per cent calcium carbonate, about 3 per cent magnesium carbonate and 1 per cent or a little more of silica, alumina and iron oxides. The specific gravity is 2.71 and the weight 169 pounds to the cubic foot. Smock states that it absorbs 0.145 per cent of water.

CATSKILL AND HUDSON

The Becraft limestone in the Hudson valley contains beds of highly fossiliferous character, with a subcrystalline texture, that have been quarried to some extent for decorative material. The stone is gray in color, with round and crescentic fragments of crinoids replaced by white calcite. The quarries near the Hudson are now producing material for Portland cement, but the George Holdridge quarries at Catskill are worked for building and ornamental material according to demand. The stone contains upwards of 95 per cent of lime carbonate and is well adapted for building stone, lime, cement and furnace flux.

LOCKPORT

The lowermost layers of the Lockport dolomite are represented by a variegated red and gray material with fossil fragments 2 or 3 inches long. In polished condition it is quite attractive, but less even in texture than the Chazy marble. There has been no production of the stone for ornamental uses reported in recent years; a specimen in the State Museum collections from the quarries of D. J. Carpenter indicates a sound material well suited for building stone.

SERPENTINOUS MARBLES; VERDE ANTIQUE AND OPHICALCITE

The Grenville limestones of the Adirondacks not infrequently carry more or less serpentine, which results from the alteration of anhydrous magnesian silicates of the pyroxene and amphibole groups. With abundant, evenly distributed serpentine there results a mottled green and white stone that possesses an attractive appearance and that has been used for ornamental purposes. A description of these marbles has been given by G. P. Merrill.[1]

At Moriah and Port Henry, in Essex county, in this State, there has been quarried from time to time under the name of white marble, a peculiar granular stone consisting of an intricate mixture of serpentine, dolomite and calcite interspersed with small flakes of phlogopite. This stone, which is an altered dolomitic and pyroxenic limestone, seems mainly free from the numerous dry seams and joints that prove so objectionable in most serpentines, and can be obtained in sound blocks of fair size. The serpentinous portions are deep green in color, while the calcareous granules are faint blue, or whitish, affording a very pleasing contrast. Blocks being quarried at the time of my visit (1888) showed, however, a very even granular texture of nearly equal parts of serpentine, calcite and dolomite in grains of from one-eighth to one-fourth of an inch in diameter, forming an aggregate quite granitic in appearance at a slight distance. The stone polishes well, and is said to be durable. In the quarry bed, where the stone had been exposed for ages, it was noticed that the calcite had weathered out on the surface, leaving the serpentine protruding in small greenish knobs. The stone has been quoted in some of the older quarry price lists at $6 a cubic foot for the best monumental stock.

[1] Stone for Building and Decoration, 1897, p. 65.

The principal difficulty in the production of the stone for the market has been to secure an even quality, as the serpentine has a tendency to gather in bunches and stringers which look like the knots in granites.

Some of the larger occurrences of the serpentinous marble are in the vicinity of Port Henry, Essex county.

The J. E. Reed quarry is 6 miles due west of Port Henry, in the town of Moriah, near the precipitous hill known as Broughton ledge. The beds are exposed for a vertical distance of 25 feet and in blocks up to 5 feet thick. They show a rather uniform mixture of carbonates and serpentines, with here and there a band of pure serpentine from a few inches to several feet long. The bands are bent and

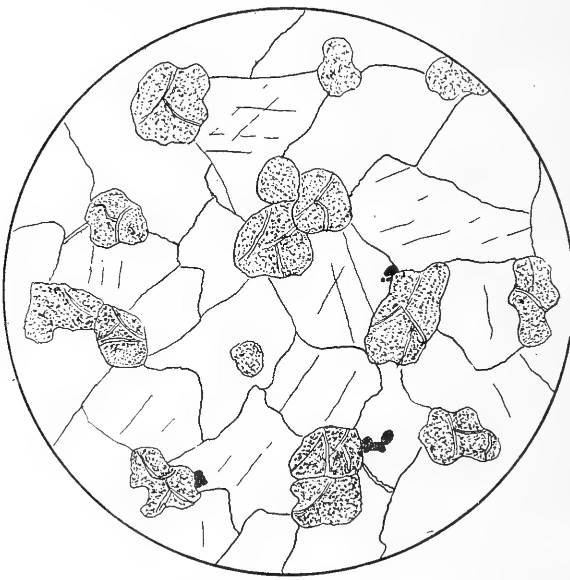

Fig. 18 Serpentinous marble, Reed quarry, Port Henry. Enlarged 10 times

twisted in a most complex way. A small fault cuts through the exposure and on the north side of it the stone is more broken. The limestone outcrops 200 feet east of the quarry site and also on the property of S. A. Foote, one-half of a mile farther east. The quarry was last worked about twenty years ago. The product was used for monuments, several of which are to be seen in the Port Henry cemetery, and to some extent for coping and lintels. When exposed long to the weather the serpentine particles are brought in relief through the more rapid solution of the carbonates. The stone is better adapted for interior decoration than outside work.

The Treadway quarry lies about a mile north of Port Henry on the brook which flows into Lake Champlain at Craig harbor. The opening shows 10 to 15 feet of the limestone.

Another quarry is north of the Cheever iron mine along the highway on property now owned by the Cheever Iron Ore Co. Two pits are to be seen on either side of the road, the one to the east exposing 15 feet of rock which shows many streaks of serpentine.

A quarry was once worked in the town of Thurman, Warren county. According to G. P. Merrill[1] the stone contains about equal parts of snow-white calcite and light yellowish-green serpentine in particles from one-sixteenth to one-fourth of an inch diameter. The texture is not very uniform.

Serpentinous limestones are found in numerous other localities in the Adirondack region, notably in the limestone areas in Essex, Warren and St Lawrence counties.

Serpentine unmixed with calcite is exposed over a large area on Staten Island. The rock lacks the translucency and rich color which are seen in the ornamental varieties, being usually dark green to nearly black, and stained by iron oxides. It carries black specks of chromite. The serpentine forms the central ridge of hills from St George on the north to a little beyond Richmond. On the borders the serpentine is mixed more or less with talc and tremolite, but in the interior contains little of the silicates, although there may be a few undecomposed remnants of pyroxene, olivine and amphibole which are the parent minerals of the serpentine. Originally the rock seems to have been a nonfeldspathic aggregate that most resembles the basic igneous types of the pyroxenite-peridotite group.[2] In most places it is badly fractured, being traversed by narrowly spaced joints and showing more or less differential movement along them, as a result probably of expansion of the mass in the alteration.

Serpentine also outcrops on Davenport's Neck at New Rochelle and near Rye, Westchester county.

An occurrence of serpentine in northern Essex county has been the source of much handsome material for museums, but has not been worked on a commercial scale. The serpentine occurs along the sides of a ravine just west of Port Douglas on the road to Keeseville. It is found only within the ravine, as above it is con-

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[1] *Op. cit.* p. 66.

[2] The derivation of the serpentine is discussed by the writer in School of Mines Quarterly, v. 22, 1901.

cealed by beds of Potsdam sandstone. The rock is a compact lustrous serpentine of light green color with scattered grains of black iron ore and flecks and clouds of the red oxide. The appearance is quite ornamental and such as to make the serpentine well adapted for polished work if sufficiently large pieces were obtainable. In the exposed section the rock is badly broken so that only blocks of small size can be secured, but it is quite likely that better material would be found deeper in the bank beyond the limits of frost action.

INDEX

The University of the State of New York

New York State Museum

JOHN M. CLARKE, Director

PUBLICATIONS

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Museum annual reports 1847–date. *All in print to* 1894, 50c *a volume*, 75c *in cloth; 1894–date, sold in sets only;* 75c *each for octavo volumes; price of quarto volumes on application.*

These reports are made up of the reports of the Director, Geologist, Paleontologist, Botanist and Entomologist, and museum bulletins and memoirs, issued as advance sections of the reports.

Director's annual reports 1904–date.

1904. 138p. 20c.
1905. 102p. 23pl. 30c.
1906. 186p. 41pl. 25c.
1907. 212p. 63pl. 50c.
1908. 234p. 39pl. map. 40c.
1909. 230p. 41pl. 2 maps, 4 charts. *Out of print*
1910. 280p. il. 42pl. 50c.
1911. 218p. 49pl. 50c.
1912. 214p. 50pl. 50c.
1913. 158p. il. 29pl. 40c.
1914. 174p. il. 33pt. 45c.

These reports cover the reports of the State Geologist and of the State Paleontologist. Bound also with the museum reports of which they form a part.

Geologist's annual reports 1881–date. Rep'ts 1, 3–13, 17–date, 8vo; 2, 14–16, 4to.

In 1898 the paleontologic work of the State was made distinct from the geologic and was reported separately from 1899–1903. The two departments were reunited in 1904, and are now reported in the Director's report.

The annual reports of the original Natural History Survey, 1837–41, are out of print.

Reports 1–4, 1881–84, were published only in separate form. Of the 5th report 4 pages were reprinted in the 39th museum report, and a supplement to the 6th report was included in the 40th museum report. The 7th and subsequent reports are included in the 41st and following museum reports, except that certain lithographic plates in the 11th report (1891) and 13th (1893) are omitted from the 45th and 47th museum reports.

Separate volumes of the following only are available.

Report	*Price*	*Report*	*Price*	*Report*	*Price*
12 (1892)	$.50	17	$.75	21	$.40
14	.75	18	.75	22	.40
15, 2v.	2	19	.40	23	.45
16	1	20	.50	[*See* Director's annual reports]	

Paleontologist's annual reports 1899–date.

See first note under Geologist's annual reports.

Bound also with museum reports of which they form a part. Reports for 1899 and 1900 may be had for 20c each. Those for 1901–3 were issued as bulletins. In 1904 combined with the Director's report.

Entomologist's annual reports on the injurious and other insects of the State of New York 1882–date.

Reports 3–20 bound also with museum reports 40–46, 48–58 of which they form a part. Since 1898 these reports have been issued as bulletins. Reports 3–4, 17 are out of print, other reports with prices are:

Report	*Price*	*Report*	*Price*	*Report*	*Price*
1	$.50	11	$.25	21 (Bul. 104)	$.25
2	.30	12	.25	22 (" 110)	.25
5	.25	13	*Out of print*	23 (" 124)	.75
6	.15	14 (Bul. 23)	.20	24 (" 134)	.35
7	.20	15 (" 31)	.15	25 (" 141)	.35
8	.25	16 (" 36)	.25	26 (" 147)	.35
9	.25	18 (" 64)	.20	27 (" 155)	.40
10	.35	19 (" 76)	.15	28 (" 165)	.40
		20 (" 97)	.40	29 (" 175)	.45

Reports 2, 8–12 may also be obtained bound in cloth at 25c each in addition to the **price** given above.

Botanist's annual reports 1867–date.

Bound also with museum reports 21–date of which they form a part; the first Botanist's report appeared in the 21st museum report and is numbered 21. Reports **21–24, 29, 31–41** were not published separately.

Separate reports for 1871–74, 1876, 1888–98 are out of print. Report for 1899 may be had for 20c; 1900 for 50c. Since 1901 these reports have been issued as bulletins.

Descriptions and illustrations of edible, poisonous and unwholesome fungi of New York have also been published in volumes 1 and 3 of the 48th (1894) museum report and in volume 1 of the 49th (1895), 51st (1897), 52d (1898), 54th (1900), 55th (1901), in volume 4 of the 56th (1902), in volume 2 of the 57th (1903), in volume 4 of the 58th (1904), in volume 2 of the 59th (1905), in volume 1 of the 60th (1906), in volume 2 of the 61st (1907), 62d (1908), 63d (1909), 64th (1910), 65th (1911) reports. The descriptions and illustrations of edible and unwholesome species contained in the 49th, 51st and 52d reports have been revised and rearranged, and, combined with others more recently prepared, constitute Museum Memoir 4.

Museum bulletins 1887–date. 8vo. *To advance subscribers,* **$2** *a year, or* **$1** *a year for division* (1) *geology, economic geology, paleontology, mineralogy;* 50c *each for division* (2) *general zoology, archeology, miscellaneous,* (3) *botany,* (4) *entomology.*

Bulletins are grouped in the list on the following pages according to divisions.

The divisions to which bulletins belong are as follows:

1 Zoology
2 Botany
3 Economic Geology
4 Mineralogy
5 Entomology
6 "
7 Economic Geology
8 Botany
9 Zoology
10 Economic Geology
11 "
12 "
13 Entomology
14 Geology
15 Economic Geology
16 Archeology
17 Economic Geology
18 Archeology
19 Geology
20 Entomology
21 Geology
22 Archeology
23 Entomology
24 "
25 Botany
26 Entomology
27 "
28 Botany
29 Zoology
30 Economic Geology
31 Entomology
32 Archeology
33 Zoology
34 Geology
35 Economic Geology
36 Entomology
37 "
38 Zoology
39 Paleontology
40 Zoology
41 Archeology
42 Geology
43 Zoology
44 Economic Geology
45 Paleontology
46 Entomology
47 "
48 Geology
49 Paleontology
50 Archeology
51 Zoology
52 Paleontology
53 Entomology
54 Botany
55 Archeology
56 Geology
57 Entomology
58 Mineralogy
59 Entomology
60 Zoology
61 Economic Geology
62 Miscellaneous
63 Geology
64 Entomology
65 Paleontology
66 Miscellaneous
67 Botany
68 Entomology
69 Paleontology
70 Mineralogy
71 Zoology
72 Entomology
73 Archeology
74 Entomology
75 Botany
76 Entomology
77 Geology
78 Archeology
79 Entomology
80 Paleontology
81 Geology
82 "
83 "
84 "
85 Economic Geology
86 Entomology
87 Archeology
88 Zoology
89 Archeology
90 Paleontology
91 Zoology
92 Paleontology
93 Economic Geology
94 Botany
95 Geology
96 "
97 Entomology
98 Mineralogy
99 Paleontology
100 Economic Geology
101 Paleontology
102 Economic Geology
103 Entomology
104 "
105 Botany
106 Geology
107 Geology and Paleontology
108 Archeology
109 Entomology
110 "
111 Geology
112 Economic Geology
113 Archeology
114 Geology
115 Geology
116 Botany
117 Archeology
118 Geology
119 Economic Geology
120 "
121 Director's report for 1907
122 Botany
123 Economic Geology
124 Entomology
125 Archeology
126 Geology
127 "
128 "
129 Entomology
130 Zoology
131 Botany
132 Economic Geology
133 Director's report for 1908
134 Entomology
135 Geology
136 Entomology
137 Geology
138 "
139 Botany
140 Director's report for 1909
141 Entomology
142 Economic Geology
143 "
144 Archeology
145 Geology
146 "
147 Entomology
148 Geology
149 Director's report for 1910
150 Botany
151 Economic Geology
152 Geology
153 "
154 "
155 Entomology
156 "
157 Botany
158 Director's report for 1911
159 Geology
160 "
161 Economic Geology
162 Geology
163 Archeology
164 Director's report for 1912
165 Entomology
166 Economic Geology
167 Botany
168 Geology
169 "
170 "
171 "
172 "
173 Director's report for 1913
174 Economic Geology
175 Entomology
176 Botany
177 Director's report for 1914
178 Economic Geology
179 Botany
180 Entomology
181 Economic Geology

Bulletins are also found with the annual reports of the museum as follows:

Bulletin	*Report*	*Bulletin*	*Report*	*Bulletin*	*Report*	*Bulletin*	*Report*
12–15	48, v. 1	79	57, v. 1, pt 2	119–21	61, v. 1	154	64, v. 2
16,17	50, v. 1	80	57, v. 1, pt 1	122	61, v. 2	155	65, v. 2
18,19	51, v. 1	81,82	58, v. 3	123	61, v. 1	156	65, v. 2
20–25	52, v. 1	83,84	58, v. 1	124	61, v. 2	157	65, v. 2
26–31	53, v. 1	85	58, v. 2	125	62, v. 3	158	65, v. 1
32–34	54, v. 1	86	58, v. 5	126–28	62, v. 1	159	65, v. 1
35,36	54, v. 2	87–89	58, v. 4	129	62, v. 2	160	65, v. 1
37–44	54, v. 3	90	58, v. 3	130	62, v. 3	161	65, v. 2
45–48	54, v. 4	91	58, v. 4	131,132	62, v. 2	162	65, v. 1
49–54	55, v. 1	92	58, v. 3	133	62, v. 1	163	66, v. 2
55	56, v. 4	93	58, v. 2	134	62, v. 2	164	66, v. 1
56	56, v. 1	94	58, v. 4	135	63, v. 1	165–67	66, v. 2
57	56, v. 3	95,96	58, v. 1	136	63, v. 2	168–70	66, v. 1
58	56, v. 1	97	58, v. 5	137	63, v. 1		
59,60	56, v. 3	98,99	59, v. 2	138	63, v. 1	*Memoir*	
61	56, v. 1	100	59, v. 1	139	63, v. 2	2	49, v. 3
62	56, v. 4	101	59, v. 2	140	63, v. 1	3,4	53, v. 2
63	56, v. 2	102	59, v. 1	141	63, v. 2	5,6	57, v. 3
64	56, v. 3	103–5	59, v. 2	142	63, v. 2	7	57, v. 4
65	56, v. 2	106	59, v. 1	143	63, v. 2	8, pt 1	59, v. 3
66,67	56, v. 4	107	60, v. 2	144	64, v. 2	8, pt 2	59, v. 4
68	56, v. 3	108	60, v. 3	145	64, v. 1	9, pt 1	60, v. 4
69	56, v. 2	109,110	60, v. 1	146	64, v. 1	9, pt 2	62, v. 4
70,71	57, v. 1, pt 1	111	60, v. 2	147	64, v. 2	10	60, v. 5
72	57, v. 1, pt 2	112	60, v. 1	148	64, v. 2	11	61, v. 3
73	57, v. 2	113	60, v. 3	149	64, v. 1	12, pt 1	63, v. 3
74	57, v. 1, pt 2	114	60, v. 1	150	64, v. 2	12, pt 2	66, v. 3
75	57, v. 2	115	60, v. 2	151	64, v. 2	13	63, v. 4
76	57, v. 1, pt 2	116	60, v. 1	152	64, v. 2	14, v. 1	65, v. 3
77	57, v. 1, pt 1	117	60, v. 3	153	64, v. 2	14, v. 2	65, v. 4
78	57, v. 2	118	60, v. 1				

The figures at the beginning of each entry in the following list indicate its number as a museum bulletin.

Geology and Paleontology. 14 Kemp, J. F. Geology of Moriah and Westport Townships, Essex Co., N. Y., with notes on the iron mines. 38p. il. 7pl. 2 maps. Sept. 1895. Free.

19 Merrill, F. J. H. Guide to the Study of the Geological Collections of the New York State Museum. 164p. 119pl. map. Nov. 1898. *Out of print.*

21 Kemp, J. F. Geology of the Lake Placid Region. 24p. 1pl. map. Sept. 1898. Free.

34 Cumings, E. R. Lower Silurian System of Eastern Montgomery County; Prosser, C. S. Notes on the Stratigraphy of Mohawk Valley and Saratoga County, N. Y. 74p. 14pl. map. May 1900. 15c.

39 Clarke, J. M.; Simpson, G. B. & Loomis, F. B. Paleontologic Papers 1. 72p. il. 16pl. Oct. 1900. 15c.

Contents: Clarke, J. M. A Remarkable Occurrence of Orthoceras in the Oneonta Beds of the Chenango Valley, N. Y.
—— Paropsonema cryptophya; a Peculiar Echinoderm from the Intumescens-zone (Portage Beds) of Western New York.
—— Dictyonine Hexactinellid Sponges from the Upper Devonic of New York.
—— The Water Biscuit of Squaw Island, Canandaigua Lake, N. Y.
Simpson, G. B. Preliminary Descriptions of New Genera of Paleozoic Rugose Corals.
Loomis, F. B. Siluric Fungi from Western New York.

42 Ruedemann, Rudolf. Hudson River Beds near Albany and their Taxonomic Equivalents. 116p. 2pl. map. Apr. 1901. 25c.

45 Grabau, A. W. Geology and Paleontology of Niagara Falls and Vicinity. 286p. il. 18pl. map. Apr. 1901. 65c; *cloth,* 90c.

48 Woodworth, J. B. Pleistocene Geology of Nassau County and Borough of Queens. 58p. il. 8pl. map. Dec. 1901. 25c.

49 Ruedemann, Rudolf; Clarke, J. M. & Wood, Elvira. Paleontologic Papers 2. 240p. 13pl. Dec. 1901. *Out of print.*

Contents: Ruedemann, Rudolf. Trenton Conglomerate of Rysedorph Hill.
Clarke, J. M. Limestones of Central and Western New York Interbedded with Bituminous Shales of the Marcellus Stage.
Wood, Elvira. Marcellus Limestones of Lancaster, Erie Co., N. Y.
Clarke, J. M. New Agelacrinites.
—— Value of Amnigenia as an Indicator of Fresh-water Deposits during the Devonic of New York, Ireland and the Rhineland.

52 Clarke, J. M. Report of the State Paleontologist 1901. 280p. il. 10pl. map, 1 tab. July 1902. 40c.

56 Merrill, F. J. H. Description of the State Geologic Map of 1901. 42p. 2 maps, tab. Nov. 1902. Free.
63 Clarke, J. M. & Luther, D. D. Stratigraphy of Cananadigua and Naples Quadrangles. 78p. map. June 1904. 25c.
65 Clarke J. M. Catalogue of Type Specimens of Paleozoic Fossils in the New York State Museum. 848p. May 1903. $1.20 *cloth.*
69 —— Report of the State Paleontologist 1902. 464p. 52pl. 7 maps. Nov. 1903. $1, *cloth.*
77 Cushing, H. P. Geology of the Vicinity of Little Falls, Herkimer Co. 98p. il. 15pl. 2 maps. Jan. 1905. 30c.
80 Clarke, J. M. Report of the State Paleontologist 1903. 396p. 29pl. 2 maps. Feb. 1905. 85c, *cloth.*
81 Clarke, J. M. & Luther, D. D. Watkins and Elmira Quadrangles. 32p. map. Mar. 1905. 25c.
82 —— Geologic Map of the Tully Quadrangle. 40p. map. Apr. 1905. 20c.
83 Woodworth, J. B. Pleistocene Geology of the Mooers Quadrangle. 62p. 25pl. map. June 1905. 25c
84 —— Ancient Water Levels of the Champlain and Hudson Valleys. 206p. il. 11pl. 18 maps. July 1905. 45c.
90 Ruedemann, Rudolf. Cephalopoda of Beekmantown and Chazy Formations of Champlain Basin. 224p. il. 38pl. May 1906. 75c, *cloth.*
92 Grabau, A. W. Guide to the Geology and Paleontology of the Schoharie Region. 314p. il. 26pl. map. Apr. 1906. 75c, *cloth.*
95 Cushing, H. P. Geology of the Northern Adirondack Region. 188p. 15pl. 3 maps. Sept. 1905. 30c.
96 Ogilvie, I. H. Geology of the Paradox Lake Quadrangle. 54p. il. 17pl. map. Dec. 1905. 30c.
99 Luther, D. D. Geology of the Buffalo Quadrangle. 32p. map. May 1906. 20c.
101 —— Geology of the Penn Yan-Hammondsport Quadrangles. 28p. map. July 1906. *Out of print.*
106 Fairchild, H. L. Glacial Waters in the Erie Basin. 88p. 14pl. 9 maps. Feb. 1907. *Out of print.*
107 Woodworth, J. B.; Hartnagel, C. A.; Whitlock, H. P.; Hudson, G. H.; Clarke, J. M.; White, David & Berkey, C. P. Geological Papers. 388p. 54pl. map. May 1907. 90c, *cloth.*

Contents: Woodworth, J. B. Postglacial Faults of Eastern New York.
Hartnagel, C. A. Stratigraphic Relations of the Oneida Conglomerate.
—— Upper Siluric and Lower Devonic Formations of the Skunnemunk Mountain Region.
Whitlock, H. P. Minerals from Lyon Mountain, Clinton Co.
Hudson, G. H. On Some Pelmatozoa from the Chazy Limestone of New York.
Clarke, J. M. Some New Devonic Fossils.
—— An Interesting Style of Sand-filled Vein.
—— Eurypterus Shales of the Shawangunk Mountains in Eastern New York.
White, David. A Remarkable Fossil Tree Trunk from the Middle Devonic of New York.
Berkey, C. P. Structural and Stratigraphic Features of the Basal Gneisses of the Highlands.

111 Fairchild, H. L. Drumlins of New York. 60p. 28pl. 19 maps. July 1907. *Out of print.*
114 Hartnagel, C. A. Geologic Map of the Rochester and Ontario Beach Quadrangles. 36p. map. Aug. 1907. 20c.
115 Cushing, H. P. Geology of the Long Lake Quadrangle. 88p. 20pl. map. Sept. 1907. 25c.
118 Clarke, J. M. & Luther, D. D. Geologic Maps and Descriptions of the Portage and Nunda Quadrangles including a map of Letchworth Park. 50p. 16pl. 4 maps. Jan. 1908. 35c.
126 Miller, W. J. Geology of the Remsen Quadrangle. 54p. il. 11pl. map. Jan. 1909. 25c.
127 Fairchild, H. L. Glacial Waters in Central New York. 64p. 27pl. 15 maps. Mar. 1909. *Out of print.*
128 Luther, D. D. Geology of the Geneva-Ovid Quadrangles. 44p. map. Apr. 1909. 20c.
135 Miller, W. J. Geology of the Port Leyden Quadrangle, Lewis County, N. Y. 62p. il. 11pl. map. Jan. 1910. 25c.

137 Luther, D. D. Geology of the Auburn-Genoa Quadrangles. 36p. map. Mar. 1910. 20c.
138 Kemp, J. F. & Ruedemann, Rudolf. Geology of the Elizabethtown and Port Henry Quadrangles. 176p. il. 20pl. 3 maps. Apr. 1910. *Not available.*
145 Cushing, H. P.; Fairchild, H. L.; Ruedemann, Rudolf & Smyth, C. H. Geology of the Thousand Islands Region. 194p. il. 62pl. 6 maps. Dec. 1910. $1.00 *cloth.*
146 Berkey, C. P. Geologic Features and Problems of the New York City (Catskill) Aqueduct. 286p. il. 38pl. maps. Feb. 1911. 75c; *cloth,* $1.
148 Gordon, C. E. Geology of the Poughkeepsie Quadrangle. 122p. il. 26pl. map. Apr. 1911. 30c.
152 Luther, D. D. Geology of the Honeoye-Wayland Quadrangles. 30p. map. Oct. 1911. 20c.
153 Miller, William J. Geology of the Broadalbin Quadrangle, Fulton-Saratoga Counties, New York. 66p. il. 8 pl. map. Dec. 1911. 25c.
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159 Kemp, James F. The Mineral Springs of Saratoga. 80p. il. 3pl. Apr. 1912. 15c.
160 Fairchild, H. L. Glacial Waters in the Black and Mohawk Valleys. 48p. il. 8pl. 14 maps. May 1912. 50c.
162 Ruedemann, Rudolf. The Lower Siluric Shales of the Mohawk Valley. 152p. il. 15pl. Aug. 1912. 35c.
168 Miller, William J. Geological History of New York State. 130p. 43pl. 10 maps. Dec. 1913. 40c.
169 Cushing, H. P. & Ruedemann, Rudolf. Geology of Saratoga Springs and Vicinity. 178p. il. 20 pl. map. Feb. 1914. 40c.
170 Miller, William J. Geology of the North Creek Quadrangle. 90p. il. 14pl. Feb. 1914. 25c.
171 Hopkins, T. C. The Geology of the Syracuse Quadrangle. 80p. il. 20pl. map. July 1914. 25c.
172 Luther, D. D. Geology of the Attica and Depew Quadrangles. 32p. map. August 1914. 15c.
Miller, William J. The Geology of the Lake Pleasant Quadrangle. *In press.*
Stoller, James H. Glacial Geology of the Saratoga Quadrangle. *In press.*
Miller, William J. Geology of the Blue Mountain Quadrangle. *Prepared.*
Martin, James C. & Chadwick, George H. Geology of the Canton Quadrangle. *Prepared.*
Luther, D. D. Geology of the Phelps Quadrangle. *In preparation.*
Whitnall, H. O. Geology of the Morrisville Quadrangle. *Prepared.*
Hudson, G. H. Geology of Valcour Island. *In preparation.*
Economic Geology. 3 Smock, J. C. Building Stone in the State of New York. 154p. Mar. 1888. *Out of print.*
7 —— First Report on the Iron Mines and Iron Ore Districts in the State of New York. 78p. map. June 1889. *Out of print.*
10 —— Building Stone in New York. 210p. map, tab. Sept. 1890. *Not available.*
11 Merrill, F. J. H. Salt and Gypsum Industries of New York. 94p. 12pl. 2 maps, 11 tab. Apr. 1893. *Not available.*
12 Ries, Heinrich. Clay Industries of New York. 174p. il. 1pl. map. Mar. 1895. 30c.
15 Merrill, F. J. H. Mineral Resources of New York. 240p. 2 maps. Sept. 1895. [50c]
17 —— Road Materials and Road Building in New York. 52p. 14pl. 2 maps. Oct. 1897. 15c.
30 Orton, Edward. Petroleum and Natural Gas in New York. 136p. il. 3 maps. Nov. 1899. 15c.
35 Ries, Heinrich. Clays of New York; their Properties and Uses. 456p. 140pl. map. June 1900. *Out of print.*
44 —— Lime and Cement Industries of New York; Eckel, E. C. Chapters on the Cement Industry. 332p. 101pl. 2 maps. Dec. 1901. 85c, *cloth.*

61 Dickinson, H. T. Quarries of Bluestone and Other Sandstones in New York. 114p. 18pl. 2 maps. Mar. 1903. 35c.
85 Rafter, G. W. Hydrology of New York State. 902p. il. 44pl. 5 maps. May 1905. $1.50, *cloth.*
93 Newland, D. H. Mining and Quarry Industry of New York. 78p. July 1905. *Out of print.*
100 McCourt, W. E. Fire Tests of Some New York Building Stones. 40p. 26pl. Feb. 1906. 15c.
102 Newland, D. H. Mining and Quarry Industry of New York 1905. 162p. June 1906. 25c.
112 —— Mining and Quarry Industry of New York 1906. 82p. July 1907. *Out of print.*
119 —— & Kemp, J. F. Geology of the Adirondack Magnetic Iron Ores with a Report on the Mineville-Port Henry Mine Group. 184p. 14pl. 8 maps. Apr. 1908. 35c.
120 Newland, D. H. Mining and Quarry Industry of New York 1907. 82p. July 1908. 15c.
123 —— & Hartnagel, C. A. Iron Ores of the Clinton Formation in New York State. 76p. il. 14pl. 3 maps. Nov. 1908. 25c.
132 Newland, D. H. Mining and Quarry Industry of New York 1908. 98p. July 1909. 15c.
1:2 —— Mining and Quarry Industry of New York for 1909. 98p. Aug. 1910. *Not available.*
143 —— Gypsum Deposits of New York. 94p. 20pl. 4 maps. Oct. 1910 35e.
151 —— Mining and Quarry Industry of New York 1910. 82p. June 1911. 15c.
161 —— Mining and Quarry Industry of New York 1911. 114p. July 1912. 20c.
166 —— Mining and Quarry Industry of New York 1912. 114p. August 1913. 20c.
174 —— Mining and Quarry Industry of New York 1913. 111 p. Dec. 1914. 20c.
178 —— Mining and Quarry Industry of New York 1914. 88p. Nov. 1915. 15c.
181 —— The Quarry Materials of New York. 212p. 34 pl. Jan. 1916. 40c.

Mineralogy. 4 Nason, F. L. Some New York Minerals and Their Localities. 22p. 1pl. Aug. 1888. Free.
58 Whitlock, H. P. Guide to the Mineralogic Collections of the New York State Museum. 150p. il. 39pl. 11 models. Sept. 1902. 40c.
70 —— New York Mineral Localities. 110p. Oct. 1903. 20c.
98 —— Contributions from the Mineralogic Laboratory. 38p. 7pl. Dec. 1905. *Out of print.*

Zoology. 1 Marshall, W. B. Preliminary List of New York Unionidae. 20p. Mar. 1892. *Not available.*
9 —— Beaks of Unionidae Inhabiting the Vicinity of Albany, N. Y. 30p. 1pl. Aug. 1890. Free.
29 Miller, G. S., jr. Preliminary List of New York Mammals. 124p. Oct. 1899. 15c.
33 Farr, M. S. Check List of New York Birds. 224p. Apr. 1900. 25c.
38 Miller, G. S., jr. Key to the Land Mammals of Northeastern North America. 106p. Oct. 1900. 15c.
40 Simpson, G. B. Anatomy and Physiology of Polygyra albolabris and Limax maximus and Embryology of Limax maximus. 82p. 28pl. Oct. 1901. 25c.
43 Kellogg, J. L. Clam and Scallop Industries of New York. 36p. 2pl. map. Apr. 1901. Free.
51 Eckel, E. C. & Paulmier, F. C. Catalogue of Reptiles and Batrachians of New York. 64p. il. 1pl. Apr. 1902. *Out of print.*

Eckel, E. C. Serpents of Northeastern United States.
Paulmier, F. C. Lizards, Tortoises and Batrachians of New York.

60 Bean, T. H. Catalogue of the Fishes of New York. 784p. Feb. 1903. $1, *cloth.*

71 Kellogg, J. L. Feeding Habits and Growth of Venus mercenaria. 30p. 4pl. Sept. 1903. Free.
88 Letson, Elizabeth J. Check List of the Mollusca of New York. 116p. May 1905. 20c.
91 Paulmier, F. C. Higher Crustacea of New York City. 78p. il. June 1905. 20c.
130 Shufeldt, R. W. Osteology of Birds. 382p. il. 26pl. May 1909. 50c.
Entomology. 5 Lintner, J. A. White Grub of the May Beetle. 34p. il. Nov. 1888. Free.
6 —— Cut-worms. 38p. il. Nov. 1888. Free.
13 —— San José Scale and Some Destructive Insects of New York State. 54p. 7pl. Apr. 1895. 15c.
20 Felt, E. P. Elm Leaf Beetle in New York State. 46p. il. 5pl. June 1898. Free.

See 57.

23 —— 14th Report of the State Entomologist 1898. 150p. il. 9pl. Dec. 1898. 20c.
24 —— Memorial of the Life and Entomologic Work of J. A. Lintner Ph.D. State Entomologist 1874–98; Index to Entomologist's Reports 1–13. 316p. 1pl. Oct. 1899. 35c.

Supplement to 14th report of the State Entomologist.

26 —— Collection, Preservation and Distribution of New York Insects. 36p. il. Apr. 1899. *Out of print.*
27 —— Shade Tree Pests in New York State. 26p. il. 5pl. May 1899. Free.
31 —— 15th Report of the State Entomologist 1899. 128p. June 1900. 15c.
36 —— 16th Report of the State Entomologist 1900. 118p. 16pl. Mar. 1901. 25c.
37 —— Catalogue of Some of the More Important Injurious and Beneficial Insects of New York State. 54p. il. Sept. 1900. Free.
46 —— Scale Insects of Importance and a List of the Species in New York State. 94p. il. 15pl. June 1901. 25c.
47 Needham, J. G. & Betten, Cornelius. Aquatic Insects in the Adirondacks. 234p. il. 36pl. Sept. 1901. 45c.
53 Felt, E. P. 17th Report of the State Entomologist 1901. 232p. il. 6pl. Aug. 1902. *Out of print.*
57 —— Elm Leaf Beetle in New York State. 46p. il. 8pl. Aug. 1902. *Out of print.*

This is a revision of Bulletin 20 containing the more essential facts observed since that was prepared.

59 —— Grapevine Root Worm. 40p. 6pl. Dec. 1902. *Not available.*

See 72.

64 —— 18th Report of the State Entomologist 1902. 110p. 6pl. May 1903. 20c.
68 Needham, J. G. *& others.* Aquatic Insects in New York. 322p. 52pl. Aug. 1903. 80c, *cloth.*
72 Felt, E. P. Grapevine Root Worm. 58p. 13pl. Nov. 1903. 20c.

This is a revision of Bulletin 59 containing the more essential facts observed since that was prepared.

74 —— & Joutel, L. H. Monograph of the Genus Saperda. 88p. 14pl. June 1904. 25c.
76 Felt, E. P. 19th Report of the State Entomologist 1903. 150p. 4pl. 1904. 15c.
79 —— Mosquitos or Culicidae of New York. 164p. il. 57pl. tab. Oct. 1904. 40c.
86 Needham, J. G. *& others.* May Flies and Midges of New York. 352p. il. 37pl. June 1905. *Out of print.*
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Catalogue of the Cabinet of Natural History of the State of New York and of the Historical and Antiquarian Collection annexed thereto. 242p. 8vo. 1853. *Out of print.*

Handbooks 1893–date.

New York State Museum. 52p. il. 1902. Free.

Outlines, history and work of the museum with list of staff 1902.

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Classification of New York Series of Geologic Formations. 32p. 1903. *Out of print.* Revised edition. 96p. 1912. Free.

Geologic maps. Merrill, F. J. H. Economic and Geologic Map of the State of New York; issued as part of Museum Bulletin 15 and 48th Museum Report, v. 1. 59 x 67 cm. 1894. Scale 14 miles to 1 inch. 15c.
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