GEOLOGY

OF THE

CITY OF NEW YORK.

GREATER NEW YORK.

By L. P. GRATACAP, A. M.

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American Museum Natural History.

FOR USE IN SCHOOLS, INSTITUTES AND CLASSES.

The Topography and Rocks of Greater New York.

THE City of New York now embraces four separate, though from a geological view, not distinct areas, viz.: The Borough of Manhattan (Manhattan Island), the Borough of the Bronx, the Borough of Richmond (Staten Island) and the Boroughs of Brooklyn and Queens (Brooklyn, Jamaica, Flatbush and Long Island City). Of these, the Borough of Manhattan and the Borough of the Bronx have a common geological expression; the Boroughs of Brooklyn and Queens are identical in geological character, and carry to its most typical limit the drift area so largely reduced on Manhattan Island by municipal changes, while the Borough of Richmond bears an individual geological structure involving peculiar features not observed in the others.

In geological affinities, if the term may be used, Manhattan and the Bronx are allied to northern or primordial, even archæan structures; Richmond, Kings and Queens to southern and recent, though, indeed, in Richmond, there is a problematical nucleus of serpentine hills, probably derivative from crystalline schists, similar to those of Manhattan Island.

In view of this diversity of feature the discussion of the topographical conditions and the geological nature of the City of New York will naturally fall into three sections; first that of Manhattan Island, with an appendix embracing briefly the similar construction of the Borough of the Bronx; second, that of Brooklyn and Queens and third, that of Richmond.

I. MANHATTAN ISLAND.

TOPOGRAPHY.

Manhattan Island, the original nucleus of the present enlarged city, is an irregular rectangle, bounded on the northwest by the Hudson River, on the north by Spuyten Duyvil Creek and the Harlem River, on the east by the Harlem and East Rivers, on the south by the basin of New York Harbor, or the interjunction of the Hudson River and the East River channels. It preserves a fairly uniform width of two miles northward to 125th Street, and there tapers into an elongated neck-like extension, having an average width of three quarters of a mile at Spuyten Duyvil Creek, its northern extremity. It is terminated on Spuyten Duyvil Creek by the wooded cliffs, defined to the beholder in spheroidal outlines by their covering of trees, as seen so attractively from the north side of the Harlem ship canal. Its lower end on the other hand, is a flat, tongue-shaped projection, formerly, before occupation, covered with low hills or slopes of stony debris, and rounding quite symmetrically on either side into the channel of the East River and the Hudson on the west. The west margin of the island, through almost its entire extent, after the easterly inclination to the southern point is passed, is a straight line (formerly less regular), interrupted by slight irregularities, and a noticeable deflection westward at 153d Street. The eastern side of the island is less regular, and besides the lateral bulge at Grand St., from Hell Gate at 92d St. to Randall's Island at 125th St. and thence to 155th St., has variously curved and re-entering borders.

This long strip, about thirteen miles in length, through its longest axis, presented, before the occupation that has now covered it with houses, and which has extended its original shore lines, many contrasts along its margins to its present shape. Swamps and low ground inundated by tide water, and bearing a growth of salt marsh grass, extended along the eastern margin of the city at the foot of the present Broad Street and Maiden Lane (old "Fly Market"), while broad emarginations formed bay-like cavities, as at the region of "the Swamp," where Pearl, Water, Front, Gold and Ferry Streets form now the emporium of the leather trade.

Again the western end of Canal Street expanded into a water covered area contiguous to the Lispenard meadows, whose alluvial deposits were connected by a stream or creek (Lispenard's creek), with the famous Collect (Kolck) pond, a depressed and bog-like pond on the present site of the Tombs in Centre St. The Tombs, fifty years ago known as "The Hall of Justice," stands about at the center of this old pond, or lake, a celebrated resort for winter pastimes, and referred to by its contemporaries as "a beautiful sheet of water."

Further north, at the foot of Rivington,* Grand, Houston, 5th, 7th, and 10th and 30th Sts., the edges of the island were eroded and frayed by a variable fringe of marshes. The island area has been almost everywhere below 14th St. added to by artificial enlargements, and these extensions of filled land have been, all along its southern limits, quite considerable.

The present Battery Park is made land. Greenwich Street, on the west side, was the former boundary of Manhattan Island, and the line of Water Street the limit on the east. The rapid currents

* Here were Marinus Willet's and Stuyvesant's Meadows, where, by common repute, at Burnt Hill Point, Manhattan Island, or Dry Dock, Kidd and Blackbeard buried their treasure. The meadows were a mile along the shore.

of both the Hudson and East Rivers probably existed to even a greater degree in the past than they do to-day, and to their wearing and tearing down the unconsolidated strata on either side, and their convergence at the south, is due the triangular extremity of the island and its contracted area. Below Barclay Street on the North River, the rock is met sloping toward the river, but in other places the mud, tenacious and rigid, forms an almost impenetrable layer over the bottom.

The present borders of the Harlem River illustrate the growth upward of mud flats, and it was over such surfaces that the filled-in areas about New York were made. They are lifted gradually toward the water level by slow accumulations of sediment. They are invaded by grass (***Spartina juncea***, wild), which, growing thicker and thicker, entraps more and more silt, and gradually creates a land surface below the water, to become a widely extended swamp-bed. Such changes are in operation along the bulkheads of the Harlem River, as seen from High Bridge or Washington Bridge, and more noticeably at Morris Docks, Kingsbridge Village, and the environs of the ship canal at Marble Hill.

Besides such contrasted conditions affecting the marginal topography of Manhattan Island, and prevalent eighty years ago along its shores, the surface of the island presented a widely different aspect from what we see to-day, and it would be difficult to re-invest the slightly undulating grades of the present streets and avenues with the hilly and abruptly sloping, or softly rounded elevations that rose above the tide-water of the bay, one hundred or one hundred and thirty feet in the, at present, lower portion of the city. It was, indeed, a manifold mound of drifted material, a surface formation of gravel, stones, sand and earth, sculptured by streams and interrupted by natural subsidences or dips in the underlying rocks, which the engineering requirements of the city encountered as the population steadily moved northward in its peaceful conquest of this wild and beautiful region.

Before reviewing some of these ancient conditions, the knowledge of which is necessarily serviceable in any study of the geology of Manhattan Island, it conveys a pleasant surprise to read this characterization by Mrs. Lamb of the picturesque natural features of its surface.

"Manhattan's twenty-two thousand acres of rock, lake, and rolling table-land, rising in places to an altitude of one hundred and thirty-eight feet, were covered with sombre forests, grassy knolls, and dismal swamps. The trees were lofty, and old, decayed and withered limbs contrasted with the younger growth of branches and wild flowers wasted their sweetness among the dead leaves and scant herbage at their roots. The wanton grapevine swung carelessly from the topmost boughs of the oak and the sycamore, and blackberry and raspberry bushes, like a picket guard, presented a bold front in all the possible avenues of approach."

The elevations of rock at Fort George (196th St.) Ft. Washington (176th St.), the Inwood Ridge (207th St.), and the Kingsbridge hills (222d St.), are familiar and yet undisturbed. Their enduring nature precludes any serious alteration. But the hills which covered the present business section of the city were made of loose material and have generally disappeared. Near 8th St. and Broadway (Sandy Hill Lane) was a hill of sand, a yellow variety, very generally found on the surface and probably representing stream agencies; this merged into a neighboring mound west of Broadway at Tenth Street. At Provost and Varick Streets was a ridge, formerly surmounted by a fort, standing in 1797, which witnessed the retreat of Washington to White Plains.

A lateral ridge, probably Kame-like in character, viz: a heaped elongated mound formed under or within glaciers, extended from Warren Street to near Canal Street, where the Lispenard farm lay. Richmond Hill, called by the youngsters of half a century ago, "The General's Woods," and where "Tivoli Garden" stood, a place of romantic loveliness, with huge oaks and chestnuts, was north of Canal Street, a genial retreat for "those on pleasure bent."

A hill, whose substratum forms the down grade to Broadway toward Canal Street, rose at Franklin Street and declined towards the still obvious hollow of Centre Street, commanding the Collect Pond and the inconspicuous city to the south. Bunker's Hill stood at the junction of Grand, Orange and Elm Streets, a steep accumulation of earth, boulder and sand, one hundred feet higher than the level of Grand St. This hill possessed considerable elevation, and from its dome, Cozzens, reviewing his boyhood recollections, says, "was seen the bay, with the hills of Staten Island still further in the south; then turning to the west the 'noble Hudson,' with the Newark mountains in the distance, the farm houses and country seats of the island, and that stupendous work of nature, the Palisades on the north, and on the east the high ridge of that fertile plain, Long Island."*

West of Broadway to Fourth St. a range of hills extended, apparently similar in character to the cobble-stone heaps that prevail in and around Brooklyn to-day. These hills were remarkable for the abundance of quail and woodcock found in their shelters. The section about Corlears Hook, the triangular point which covers the eastern terminus of Grand St. to Front, and west to Division, was broken by undulating surfaces, and some of the hills were of

* An interesting observation was made at this spot. A fort had been built at its summit and in the centre of its enclosure a well was formed, which no doubt served its garrison, and indeed supplied water as late as 1800. But as the surrounding hills were lowered, and the immediate vicinity of the well itself on Bunker's Hill was reduced in elevation, the well became quite dry, a significant proof of the surface origin of its supply.

marked altitude, as high as eighty feet, and were remarkable from the presence of large boulders which were more numerous here than over the rest of the island.

Murray Hill, a flexure of gneiss rock, to-day is a noticeable protuberance, swelling with a gradual rise from 34th St., sinking towards 42d St., and reaching from Lexington Ave. to Broadway, with an imperceptible prolongation northward, melting into the surfaces of Central Park. Here at 42d St. and 5th Ave., at Reservoir Park, a hill of the rudest and most heterogeneous mixture of stones and gravel and boulders, cemented together into a matrix of almost impenetrable density, existed, crowning the underlying schist. Between such hills, now removed, small water holes, or ponds, existed at favorable junctures, and occasionally a stream or rivulet crept from the higher levels and wore a sinuous course to the east or west, emptying into Hudson River, or the East River channel. Such was the "Minetta water," running into Bollus Pond at Dowling St., also the ditch that connected a little pond in Manhattan Square with the present large lake in Central Park, and escaped thence to the East River, also the stream that fed Harlem Lane, about 130th St. on the west side, and the larger creek and streamlets at its head, running into Hell Gate at 92d Street.

Reverting now from this somewhat reminiscent and historical survey of these surface characters which reveal the original topography of the more altered areas of the island, and are more naturally pertinent to its lower sections, we will look northward and decipher the constructional lines north of 59th St., without regard to its geology, only aiming at a general sketch of its relief. The process of grading and leveling and creating the orderly adjustments of a city, has reduced the exceptional elevations, and only in the yet northern portions, or in the natural contours of Central Park, are the uneven surfaces preserved, while in Central Park they are greatly masked.

The bosses of rock west of the park, north of 59th St., have been largely removed, but sections showing their former height are here and there preserved, and the rock faces within the Central Park wall, along Eighth Ave., exhibit their nature. Besides a succession of barren folds of rock, holding pockets of debris, there were deep basins and valley-like pits between them, as late as 1880, holding the hovels and huts of a Bohemian domiciliary, and of gardeners and squatters.

The east side of the city was more thoroughly reduced to order before the west side, and showed only in isolated squares the bluffs of rock standing vertically aver the streets cut through them, as between Third and Fifth Aves. above 90th St. A base leveling, as it were, has been instituted, and except for the unavoidable undulations of the surface, its surficial characters, of course, have disappeared. On the west side, in the region of Claremont, now 116th St. to 125th St. the land rises into a ridge of commanding height, forming Cathedral Plateau, breaking down in terraces to the Hudson River, and declining more abruptly into the Harlem Flats at Morningside Park. A birds-eye view of this region from 59th St. to 125th St. on the west would have presented not many years ago a blistered and contorted surface of rock carved out with creases and sinuous depressions, with also a general gradient upward to the north and somewhat coarsely traversed by east and west folds. In many portions of this area there were quite deep valleys, as in and about 76th St., since raised by material removed from the hills to the general street grade.

From Morningside Park the eye surveys an alluvial or drift plain towards the east, terminating in the blue thread of water of the Harlem River and broken by the pinnacle-like prominence of Mt. Morris Park, itself the terminal peak of an interrupted ridge, stretching southward between Fifth and Third Aves. Northward the transverse gorge or clove at 125th St. bending north-westwardly to 129th St. is encountered, and beyond it from Convent Avenue, another upheaval carries the rocky prolongation, still rising to Washington Heights at 155th St. to 176th St. Transferring our aerial seat of vision to above this point, we see a spur striking northward to Fort George, and a divergent axis of elevation somewhat parallel, also running northward into the backbone of Inwood, overlooking the Kingsbridge road, while at our feet, peacefully embosomed between precipitous or receding banks, the Harlem River flows, leading the gaze northward to Fordham Heights and to a broad back of elevation which forms the eastern embankments of the Hudson River. Still continuing our imaginative flight, we find our station in Inwood at the northern limit of the steep ridge overlooking the Lafayette (or French) Boulevard. Immediately below us is a depression leading to the river, and on the north side and to the east of it rise the beds of the Kingsbridge limestone or marble, which, again to the north-west and west, at the extreme end of the island, succumb to the picturesque ledges of gneiss at Spuyten Duyvil Creek.

If now we suddenly transport ourselves to the east side of the island and continue a survey southward, we find in Harlem in the latitude of Randall's Island, traces of such hummocks and hills of drift, as characterized the region south of 23d St., while beginning at 89th St., opposite the slim morassy tip of Blackwell's Island, we encounter a rim or ledge of rock, sometimes precipitous and again retreating, continued south toward 50th St. the basement of a meridional ridge, or one running north and south, like those we have encountered, somewhat, *en echelon*, on the west.

Gathering together the results of such a topographical sketch, and eliminating simply varietal features, we find Manhattan Island to be a ridge, generally rising in elevation towards the north, sinking towards the south, where its rocky floor has disappeared below the mantle of surficial detritus, drift and sediments piled up over it and broken up into north and south alignments of hills, intersected and diversified by flats, valleys, passes and ravines, and again revealing broad undulations which cross these transversely, somewhat irregularly related to the north and south lines, but still unquestionably present, at Murray Hill, the fold at 59th and 93d St. Cathedral Plateau and Hamilton Grange. There is also quite discernible a shifting westward of the highland towards the channel of the Hudson, leaving a bay and semi-estuarine level on the east at the junction of the Harlem and East River channels and the Sound with, however, rocky prominences on the west, immediately or almost in contact with the East River below 98th Street.

Two water channels deeply excavated in rocky basins bound it on the east and west, and two notable depressions, that of Manhattanville and Inwood, cross it obliquely, while a gash, or fault, at Spuyten Duyvil, subsequently eroded into a water-way, separates it from identical formations to the north. Its present features are doubtless due to comparatively modern agencies (quarternary), but its origin lies far back in geological time, and is coincident with those crustal movements which have formed the Appalachian chain.

Class directions. Let the teacher draw on the blackboard an approximate outline of the Greater New York, and separate the different boroughs, and with colored chalk indicate the water courses and the longer masses of rocks, as the serpentine of Staten Island, the gneiss ridges north of 110th St., exposures along the East River, show the drift areas on Manhattan Island, in Brooklyn and Staten Island. (See accompanying paper.) If the map is given some permanence, by being drawn on paper and hung in the class room, observations of rock outcrops can be marked down from week to week, as found by the pupils, or the teacher, until the sketch gradually matures and exhibits existing localities for outcrops.

This map can be roughly drawn, certain conspicuous centers being indicated for reference, as City Hall, Union and Madison and Washington Squares, Central Park, the Harlem Bridge, and the Avenues.

The topography of Manhattan Island displays features directly correlated with its geological structure. They are naturally its expression. The Island presents three marked topographical divisions. First, that south generally of 23d Street; second, that south generally of 120th Street; third, the remainder of the Island.

The first embraces a region rudely defined by a V shaped northern limit running from about 21st Street on the East River to near 13th Street on Broadway, and there meeting a line passing to the Hudson at about 31st Street. The area to the south of this line presents almost no exposures of rock, but has had a diversified surface of hills of gravel, sand and earth intermingled and confusedly dotted over with large boulders.

The excavations made for the large buildings have penetrated through the present levels and revealed the mixed composition of the loose strata still incumbent over the deeply seated rocky basement which forms the substantial support of these lofty tenements, The origin and nature of this deposit is connected with the glacial vicissitudes which have carried from the north and the higher portions of the island itself, this mantle of debris. It has progressively disappeared above the grade level of the streets as the city has advanced its populated limits. A few areas yet reveal its nature; elevated sections of drift hills, such as that at Third Ave. and 66th St.—now reduced for the occupancy of the Elevated R.R. engines—but, except for the revelation of its character, made by excavations, it would have no witness now in the lower portions of New York,

The recurrent opportunity of putting up great buildings, and the necessity of placing their first tiers upon solid rock have led to a reasonably complete exposure of these loose beds. The succession of beds is variable, but a general resemblance, apart from the differing thicknesses of similar strata, is preserved. Along the river a channel margin, and in all places where made land is found, the first surfaces are composed of such artificially introduced material, below this, usually marsh mud, and in descending succession, sands, gravel, clay and rock.

There are variations of such sections, and the clay beds, sands, gravel and mud silts, may be combined in changed relations with two or more separated beds of each. A clear conception of the actual order is given by the following list of sections which is here in part quoted from Prof. J. F. Kemp's Geology of Manhattan Island; in part derived from Mather's Report, 4th District, N. Y.; Cozzen's Geographical History of Manhattan Island; in part from results published in the Scientific American, and in part from inquiry or observation.

Broad St.—Made ground, 4 feet, yellow clay 6 feet, gravel and sand, 19 feet, gray clay 10 feet; 39 feet to rock.

Trinity Church—Gravel and sand, 26 feet to rock.

Washington Market—Made earth, 10 feet, river mud, vegetable matter, sands, clays, alternating 50 feet, sand and gravel 10 feet; to rock 70 feet.

College Place—Surface 20 feet, stratified sand and gravel 60; *in all* 80 feet.

Fulton Market—Made ground 15 feet, stratified sands, blue clay, river mud 115 feet; in all 130 feet.

Hall's Hotel, north of Fulton Market—Made ground, clay, mud and gravel; to rock, 126 feet.

City Hall—90 feet to rock.

New Church St.—86 feet; quick-sand.

A very deep bank of sand covers the region along Park Row; the former Herald building, Western Union building, the office of the Times and Tribune were all erected on this sand. The dry, pure sand affords a useful foundation, but when mingled with clay it becomes one of the most treacherous; pressure developing slipping surfaces in all directions.

The Welles' Building, lower Broadway, rests upon a hard pan or clay (?) in which were found the bottoms of old wells. Excavations were here made through quick-sand and the same stratum was encountered in the Western Union Building in Broad Street. Builders identify an irregular water-course flowing as far north as 18th Street; again at 15th Street and Fifth Avenue; again at the Jefferson Market Court House, 8th Street and Sixth Avenue, and again at Spring Street. This continuity may be questioned, but the quick-sand is a very disagreeable fact, a head of water keeping it mobile and fluid.

St. Francis Hospital, Fifth Street—100 feet to rock.

Rivington and Columbia Streets—old well, 20 feet; quick-sand, 10 feet; marsh mud and clay, 20 feet; gray clay, 10 feet; to rock, 60 feet.

Foot of Jefferson Street—mud, 10 feet; sands, gravel and clay, 40 feet; total, 50 feet.

Allen and Hester Streets—old well, 40 feet; quicksand and gravel, 20 feet; clay, 2 feet; coarse gravel and sand, 5 feet; to rock, 67 feet.

Centre and Reade Streets—coarse gravel, 30 feet.

Tombs—made ground, 40 feet; black mud, 30 feet; blue clay 5 to 10 feet; gravel to rock, 80 feet; in all, 155 feet.

Grand and Wooster Streets—made ground, 40 feet; mud, clay, sand and vegetable matter, 20 feet; blue clay, 6 feet; coarse sand and gravel, 6 feet; to rock, 72 feet.

Bleecker Street and Broadway—stratified sand and gravel; 42 feet to rock.

Perry and West Eleventh Street—sand, 40 feet; red clay, 23 feet; to rock, 63 feet.

Ninety-ninth Street and Second Avenue—made ground, 8 feet; dock mud, 18 feet; sand, 12 feet; total, 38 feet.

Avenue D and 10th Street—made earth, 6 feet; marsh mud, 10 feet; quick-sand, 12 feet; shore sand and gravel, 53 feet; hard pan, 6 feet; coarse gravel, 3 feet; total, 90 feet to rock.

I am indebted to Messrs. Kimball and Thompson for the subjoined valuable information as to recent borings in the soils above the rock-beds in lower New York.

The borings for the foundation of the Manhattan Life Insurance building, 66 Broadway, showed:—sand, 34 feet, conglomerate (coarse gravel)? 6 feet; boulders, 2 feet 8 inches; to rock, 42 feet, 11 1-2 inches; excavation in gneiss, 24 feet.

Standard Oil Building,	hard	pan,	44	feet	below	Broadway	curb.
American Surety	"	"	71	"	"	"	"
Empire	"	"	54	"	"	"	"
Washington Life	"	"	75	"	"	"	"

Mr. Chas. H. Deans remarks on above, that "in all the work the material over the hard pan was practically the same; being a very fine sand, with a great deal of fine mica and some loam in it. In some spots it was an actual quicksand."

The "hard pan," is a compact clay, packed with small stones.

In the discussion of this group of formations we find that it consists of two geological members a series of laid beds which have been deposited by running water, or laid down under water in some way, and a subsequent superficial and heterogeneous aggregate of drift material which has been accumulated by ice action. The sand and clay beds represent the results of water action, re-assorting drift material from some higher level; or, indeed, they may be a deposit formed from the products of decomposition of the island rocks before the ice age was initiated, while the top river mud found along the margin sinuations, pond bottoms and estuarine levels, is a distinctly modern or alluvial deposit.

This alluvial deposit has a further extension in the mud now forming the bottom of the Hudson River; a deposit, which has increased since cultivation of the drainage basins in the northern part of the State began. The opening up and tilling of the ground and the loosening of the formerly forest-covered soil has greatly increased the amount of earth, carried away in rains and freshets, and deposited in the Hudson.

The beds of clay and sand vary in extent and thickness, as might be expected from any sediment deposited under water, and fluctuating in the rate of its deposition at different points, or unequally accumulating at different times. In some sections the clay appears absent; never the sand or gravel. There thus seems to be deposited over the eroded and hollowed out edges and inequalities of the underlying rock, in lower New York, from forty to one hundred feet beneath the surface, a blanket of clay and sand which has a very considerable thickness. The sand beds are of importance where they reach an extraordinary depth. The foundations of the St. Veronica Church in Christopher St., between Greenwich and Washington Streets, was laid in sand, and the quality was of sharp sand, viz: such as has been deposited before being subjected to much disturbance, or a long transportation by water. The quantity was so considerable as to defray by sale the actual expense of the contractor. Again, on Broadway, at the corner of Ann Street, the beds of sand excavated for the foundations: first, of the Herald Building (1870), and, later, of the St. Paul (1896), were of remarkable depth.

It has been usual to regard this assortment of beds of sand, gneiss and gravel as entirely quarternary, or derived from drift. The actual confusion of material, originating in the sub-ærial erosion and weathering of the rocks of the island, with the glacial material pushed down over these rocks, and partially made up of their topmost films would, in any case, be inevitable. But that the deep deposits of sand and clay might represent shore sands and clay beds formed in the weathering of the gneiss ridges of Manhattan Island ages before the Ice age, or its succeeding quarternary epochs is a violent assumption. The results of the decomposition of the rocks of Manhattan Island, formerly far more elevated than they are to-day, were doubtless removed to the south, and may, indeed, have formed the cretaceous and tertiary beds beneath the surface of Long Island.

The geological conditions are readily understood, as indicated by these deposits. This lower section of the island is underlaid by the same kind of rock as forms the hills, prominences and ridges northward, and over this floor a burden of loose strata has been accumulating, rising in a succession of beds, each individually homogeneous, or relatively so, as clay sand and gravel. These beds originated by water action upon drift material heaped up possibly north and south of them, at any rate near their present position, an action which washed out the clay particles and permitted their settling in clay beds. This action, also, parted the sand and gravel, and under the impulse of torrents, or slow shore washing, completed the separation of each. During the long periods required for this gradual re-assortment, the island underwent changes of elevation, alternating, probably, over a hundred feet, since, on the one hand, gravel beds formed in swift and shallow streams, are found fifty feet below water level, and must have been much nearer the surface when made, and, on the other hand, sand hills, also indicating water action, are recorded 80 feet above tide. In many places such modified beds were capped by mingled aggregates brought hither by ice which, in rolling hills of stones, pebbles and boulders formed the original surface of the island over much of its extent, the higher hills and more remarkable boulders seeming to have been concentrated eastward about Corlears Hook. As present conditions supervened, river mud and other debris accumulated and such swamps as Collect pond developed. This pond had apparently itself, undergone oscillations in its level, as Cozzens speaks of the soft mud from its bottom being charged with salt, as if the channel waters had entered it. The depression of the land allowed the rapid currents of the two encircling rivers to attack the drift debris, loading the inland portions of the island, and in conjunction with its own drainage form these beds of sand, gravel and clay which, again upon re-elevation, were again disturbed and submerged, to be covered by later beds, until the island assumed its present status. What striking changes may have been produced by still greater elevations will be described in the resumé of this article. The nature of the boulders found in this portion of the "drift" are mentioned in the accompanying paper on the "Evidences of Glacial Action," &c.

ROCKS OF MANHATTAN ISLAND.

We have seen that the first topographical section of Manhattan Island, that generally south of 23d Street, is a drift area, and that the crystalline rocks underlying it are not met at the surface, and that their nature and contents must be determined elsewhere. It is in the second section, or that portion of the island generally south of 110th St. where all the rocks of the island, with the exception of the Kingsbridge limestone, are typically shown, and which we are now to consider.

In this section we find that while drift is a prevalent surface formation, the underlying rock is also seen, and has formed numerous and high ridges before it was levelled by municipal requirements. This rock is *Gneiss*, the omnipresent rock of the island showing varieties and contrasts in appearance, and carrying within it associated rocks, bearing a wide range of minerals, and exhibiting the singular effects of compression in its folds and plications.

The term "Gneiss" embraces an extension of applications to many mineralogically varied rocks, in all of which, however, the stratified—*layer like*—character is conspicuous. The teacher taking up a large, smoothed fragment of gneiss, or mica-schist rock, or noting their appearance in any broad exposure, will be struck at once by the lined or banded structure. They present a streaked appearance, and this leaf-like arrangement of the minerals, their juxtaposition, as it were, in sheets, is its character. So that the word gneiss initially indicates structure, which is further revealed in its *schistosity*, the property of splitting in slabs or plates.

With this generalized application the gneissoid rocks on Manhattan Island, may be grouped conveniently, thus: Gneiss (proper), Mica Schist, Hornblendic gneiss, and Hornblende schist, with a gneissoid intermixture of limestone and mica, mentioned below.

Gneiss, as found on Manhattan Island in most cases, is a laminated granite usually, in its mica-schist section, having a larger percentage of mica than granite, a smaller percentage of feldspar, and quartz in about equal amounts, grading again into a very quartzose or feldspathic rock, with the mica sensibly diminished. Its components are mica, quartz and feldspar. The mica may be the potash mica—muscovite—or the magnesium iron mica—biotite or phlogopite; lepidomelane—iron mica—and lepidolite lithia mica may and do enter into the composition of gneisses elsewhere, but not on Manhattan Island. Gneiss constitutes, with mica-schist, the larger part of Manhattan Island, in fact forms practically its entire mass, the exceptional constituents of granite, limestone and serpentine aggregating less than one per cent. of the whole superficial extent, disregarding entirely the drift division.

THE GNEISS (PROPER).

As already defined gneiss consists of mica, feldspar (usually orthoclase), and quartz. Its characteristic structure is evident wherever seen. It, however, fails to preserve a uniform composition. It becomes in many places a mica-schist, and it grades in the limestone areas into a calcareous schist, wherein the mica is largely intermixed with limestone, while it holds, closely interbanded with itself, granite strips which maintain the bedding of the gneiss, but are readily separated by their white appearance and the irregular arrangement of their components, the same as those of the gneiss, quartz, mica and feldspar. Besides these changes in nature it alternates in places with hornblendé-schist and hornblende-gneiss, namely, rocks composed almost entirely of hornblende, or hornblende, with a slight admixture of feldspar and quartz, and again the gneiss holds many accidental minerals, which sometimes vary or completely change its local aspects. Gneiss rocks predominate over the west side of Manhattan Island and graduate into mica-schists on the east, though no exact demarcation is observable. They are usually gray to dark, their color varying with the presence of the black (biotite) mica, and the percentage of feldspar and granite. In many instances the gneiss is very quartzose and solid ribbons of spar quartz alternate with narrow strips of mica.

(Class directions.—The teacher should take into the class room some characteristic example of this rock, explain its composition and structure to the class, call the attention of the pupils to its different constituents, the flakes of mica lying in one way, like scales laid down in order on one another, the gray granules of quartz, and the white particles of feldspar gathered somewhat by themselves in lines; then crushing the fragment under a hammer, let her separate the different minerals into piles, revealing their mutual ratio, and objectively demonstrating that the rock is a MIXTURE of these separate minerals. Let her accent the difference of the two micas—muscovite and biotite—the former a silicate of alumina and potash with water and light in color, the latter a silicate of alumina, magnesia, iron and potash with water, and dark in color; let her note the relative hardness of all the minerals in the gneiss, the soft micas, the harder feldspar, and the very hard quartz.

It is to be observed that the gniess is regarded in this paper as including rock varieties which Prof. Kemp has termed mica schist viz: the very micaceous beds in which a granular cement of quartz and feldspar occurs, interleaved with, or penetrating the mica. The harder gray and dark gneiss is less commonly seen, perhaps, than the more micaceous gneisses, which become mica schist upon the almost complete disappearance of the feldspar and quartz. The gneiss thus presents greatly contrasted conditions, and they are generally dependent on the greater or less development of mica.

Some excellent exposures of gneiss and its mutations are to be found in the Transverse Road across Central Park at 79th St.; at the entrance to the Park from 8th Avenue at 106th St.; along the bluffs at 110th St. and the Cathedral site; in the blocks of rock left standing near Central Bridge, where there is much variegation of color; in the ridge culminating in Washington Heights, along the Convent grounds, and beyond, while in cellar and water pipe excavations above 42d St. it is often seen to great advantage, its almost vertical sheets, cleaving off in huge plates, being admirably shown. Sites also in west 93d St., west 123d St., and between 5th and 4th Avenues at 120th St., Harlem, can be profitably studied. This gneiss underlies all the island to its extreme southern point. Cozzens (1843) mentions its occurrence on the surface of the Battery, also at the east end of 14th St., while in Bleecker Street a boring for water passed through five hundred feet of gneiss early in the century. This same formation extends below the mud deposits of the bay, crops up in Governor's Island, underlies Long Island and Staten Island, and reaches westward and eastward as the earliest and basal geological formation, though again itself underlaid by older rock to the north. An attempt has been made by Dr. Merrill of the State survey to separate the gneiss of Manhattan Island from those similar rocks at Yonkers and Fordham, a demarcation alluded to in another section of this paper.

MICA SCHIST.

The mica schist on the island, if it were understood to include the very micaceous beds of gneiss, would be almost more abundant than the gray, harder gneiss. Where characteristically shown, it is a rock made up of mica plates, usually larger than the scales of mica in the gneiss, the plates compacted and interruptedly imbricating (shingle-like), forming a mica rock quite cleavable and almost entirely composed of this one mineral.

There is a natural difficulty felt in determining the mica schist and the gneiss, at the point where they grade into each other, and become indeterminately confused. The typical gneiss is a harder gray to white compact rock, showing linings containing considerable quartz and feldspar with the mica reduced to specks. As the mica increases in quantity the rock becomes softer, more schistose, or cleavable, and the quartz and feldspar diminish, dwindling down almost to extinction, when the term mica schist becomes applicable.

Unless cut through, neither gneiss or mica schist display their structure, weathering only into rusty brown surfaces, usually splendent with mica, when mica is predominant, or dull gray-streaked slopes, when the feldspar and quartz reach a more normal development. Both mica schist and the micaceous gneiss easily retain water, and undergo a disintegration which completely breaks down their coherence, so that while retaining their original relations the components crumble with the slightest pressure. This necessitates their extensive removal for considerable depths, when built upon, in order to reach the unchanged rock, as in the case of the Astoria Hotel, whose foundations penetrate thirty-five feet into the gneiss and the river piers of the Harlem Bridge, which rest upon layers of rock forty-five feet below their first surface.

Prof. Kemp has remarked the tendency of the gneiss "to break up into large, irregular rhombohedra, or inclined prisms," producing a "step" structure, and instances the north end of Tenth Ave. and the foot (east) of 50th St. The very micaceous gneiss which, in some nomenclatures, passes for mica schist, can be seen at a number of exposures on the east side, beginning at the East River Park, 86th St. and East End Avenue, where granite veins are present. From this point southward, at 80th Street, with granite veins on the river's edge with drip trap boulders; at 77th and 75th St. and the river; at 73d St. in a moderately high bluff, east of Ave. A, and rather more micaceous, with fewer granite veins. It can be easily followed to 70th St., and rises on either side of the Avenue, forming at 59th to 58th Sts. and at 51st and 50th Sts. the steep wall of the East River channel, through which the tides surge tempestuously. Opposite this last point it can be seen in hummocky islands west of Blackwell's Island in the middle of the stream.

It weathers into a black, rusty surface, apparently becoming covered with a ferruginous (iron) exudation.

GRANITE.

Granite is a mixture of feldspar (on Manhattan Island, Orthoclase, ***Microcline*** [potash feldspar] and Oligoclase [lime soda feldspar]) mica and quartz, indiscriminately combined, though in the fine grained forms maintaining a fairly even development.

Class directions: Let the teacher take some typical granite, explain its composition, separate its components, and draw attention to the contrasted arrangement of its parts, as compared with gneiss or mica schist. Also secure specimens of varying coarseness showing the closer admixture of the minerals in the fine-grained varieties.)

The granite on Manhattan Island reaches in one point a development entitling it to rank as a substantial element in the island construction, and that is on the west side from about 48th St. northward to 55th St., where a wide bed of it, now covered with buildings, exists, probably at some past time attaining considerable elevation. This granite can still be seen at 50th St. and Eleventh Avenue projecting from the south side of the street, a few feet west of 11th Ave.

The granite is coarse pegmatitic and of much beauty. It is irresistibly suggested that such masses, as the volume to which this may be referred, were intrusive, as the large and similar veins in the Borough of the Bronx, that they did not originate as the smaller conformable or cross veins of granite did, from some re-arrangement of the gneiss in fusion but were actually pushed through the gneiss beds.

This granite on the Hudson River has been used for building purposes in the past, and the remarks made by Dr. Gale, in his report to the State Survey, published in 1839, are of considerable interest, as indicating its development.

He remarks "that the far greatest quantity of granite was taken from 44th to 47th Streets, near, and on Tenth Avenue, and that large quantities are put into shape for the Croton Water-Works;" "used also for facings on the line of aqueduct and for culverts." It is well known that there were gneiss quarries on the island, where the gneiss was taken out for building purposes. The granite here on the west side was similarly extracted.

Throughout the gneiss rock of the island granite veins occur, and their relations to the enclosing gneiss is interesting. They can be readily recognized at some distance as white bands, and they are of all widths, sometimes thin strips, again broader zones enlarging into very conspicuous veins, and they are arranged as parallel enclosures in the gneiss, looking like white ribbons on a gray or black cloth, and again piercing the gneiss films and beds at oblique or even right angles. They vary in grain from a rather fine texture to exceeding coarse varieties, in which occur broad crystals of mica, large cleavage plates of orthoclase and abundant quartz. They form the matrix of many of the most beautiful and striking mineral developments of the island. Garnet, Tourmaline Apatite, Beryl, Columbite, Menaccanite, are found of rare or unusual size in these veins, usually central in position, and not along the line of contact with the neighboring gneiss, while in one or two exceptional instances the rare minerals Monazite and Xenotime have been met with; and their probable mineral contents yet remain far from exhausted.

The granite veins already suggested are referable in formation to two classes, those which occur bedded with the gneiss, preserving a rather complete parallelism with the enclosing gneiss, and which seem synchronous in origin with it, and those which cut across the gneiss layers in various directions, and seem subsequent in origin to the gneiss itself. The conformable veins, viz: those which lie in parallel bedding with the gneiss are often flexed and bent with the gneiss sheets around them, though in such cases the veins are usually narrow. They stand in other cases in vertical partitions like white walls between the separated gneiss beds, and again when apparently parallel, if traced down a cliff face, they deflect a little right or left, impinging unequally on one side or the other of the gneiss. A striking feature in most of these conformable veins is their quite uniform width for long distances. Many of these veins appear in the glaciated surface of Bronx Park in the ledges around West Farms. They can be seen at a number of points in Central Park; one of these of a considerable width, aproximately conformable with the mica rock on either side is most conspicuous at 106th St. and 8th Ave. in Central Park, where its mica, feldspar and quartz are falling away in sand and clay.

The veins which intersect the gneiss are displayed quite generally where there have been any excavations made, or where the higher ridges have been blasted away. The grain or fabric of the granite varies greatly. The big vein in West 93d St. is a very fine-grained form,and Mr. Gilman Stanton has observed that from at least 87th St. to 95th St. the same constitution prevails in all the granite veins, while farther north in this same region near Grant's Tomb, a granite vein was highly individualized in its component slabs of orthoclase being taken out more than a foot in diameter. One of the narrow veins in 110th St. shows a border of interlocked mica and feldspar, with a vein line of quartz about an inch and a half wide, occupying the exact center of the vein. As mentioned below, the line of contact between the gneiss and granite is often sharp but, by no means invariably so, the granite merging and mixing in the gneiss walls on either side. The apparent straightness and even width of the veins is also often deceiving. A closer examination reveals expansions, undulations and moderate swellings or constrictions. The conformable granite veins become mere threads in places and in cores taken from deep well borings, as that made under the Fifth Avenue Hotel, they recurrently appear every few feet or even inches. The line of contact of the granite with the gneiss is often sharp and the edge of the granite vein is a strip of feldspar against the mica—contrasting by its frequently black color—of the gneiss. Allied to these granite veins are lenses, or intercalations of quartz, or quartz and feldspar, or feldspar alone, which interrupt the surface of the gneiss sometimes in long ribbons, or else pinched out into short lengths. These interleavings, knuckles and balls of granite are often exposed in blasting away the gneiss. They are formed in place, embedded in the schist, and frequently they mottle the surface with streaks of granite which merge into quartzose gneiss as if it were only a phase of re-arrangement of the gneiss itself. Their hardness has resisted weathering, and they stand out like mouldings, and are easily traced by the eye from a considerable distance, as those on the rock slopes of Morningside Park as seen from Manhattan Avenue.

The second class of granite veins are those which cut across the mica schist or gneiss and sometimes are seen intersecting other granite veins. They are less uniform in width, expanding and contracting and disappearing, in some instances, in reduced or vanishing strings, suggesting the filling of crevices or cracks, produced by shock. They are often curving ribbons, like a drawn out ringlet, seen on the face of the gneiss.

A cross vein of granite could formerly be seen in West 93d St., between the Boulevard and the Riverside Drive, transverse to the foliated gneiss, appearing a sinuous and quite even patch of white across the gneiss for a hundred feet, with an average width of a foot and a half. The cliff is now largely destroyed on the north side of the street, though the vein on the south side (Figs. 1 and 2) can yet be seen sharply angulated or bent at one side.

Another vein was formerly visible, running vertically up a face of gneiss at the entrance of the grounds of the Convent of the Sacred Heart, from 126th St., a very striking and impressive example. Again a third conspicuous vein running oblique to the gneiss, uniform in width, and manifesting something of a dike-like character, is seen on the Speedway, some yards from its southern entrance, while others, more conformable and wider, are seen below Ft. George. The mica leaves are arranged upon its contact (that of the first) with the gneiss on either side, and quartz and feldspar crowd, in rather well developed crystals, its center. This vein resembles an intrusive dike of igneous rock, the slow cooling of its contents permitting a coarse development of its crystalline elements, but the contact line of foliated mica may forbid this assumption. Some of the smaller veins with their irregular penetration of the surrounding gneiss is shown in the adjoining figures taken from sections, now removed west of Amsterdam Avenue, at 78th Street (figs. 3 and 4).

The feldspar of all the granite veins varies in color from white to pink orthoclase and a delicate green oligoclase, which under a low magnifying power displays the straight rulings of polysynthetic twinning, viz: the striae, like the finest lines produced by the contact of many individual plates of the mineral. Garnets of crystallographic perfection are found attached and inserted in the feldspar of the larger vein as those discovered by Mr. Gillman Stanton in 1888 at 62d St and the Boulevard, those found by Mr. Niven on Washington Heights, and the large garnet (Fig. 5) now belonging to Mr. George F. Kunz, extracted from a vein in West 35th St.

Tourmalines are taken out from the quartz of the granite and, as described in the section on the minerals of the island, many other species, associated with these more common and conspicuous types. The discussion of these gneisses and granite, and their relative ages, and the probable age of the complex or group they constitute follows in another section.

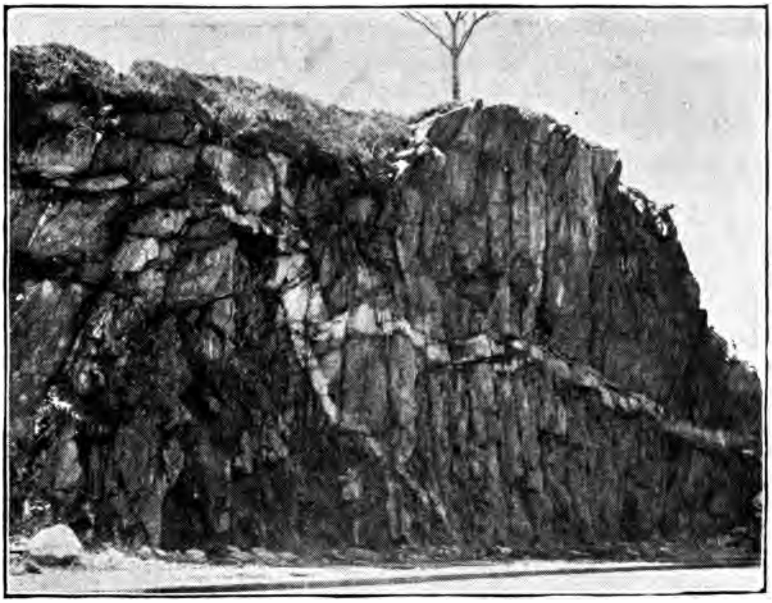

Fig. 1—Riverside Drive and 93d St., south side, showing granite vein crossing gneiss beds.

The weathering and decay of the granite is characteristic, and can be studied at a number of localities The feldspar softens into a white kaolin or clay, through which particles of quartz appear. and undecomposed granules of feldspar. This is conspicuous at 106th St., in the face of rock on 8th Ave. (fig. 6) within the wall of Central Park; decaying granite was uncovered in the excavations for the cellar of the American Museum of Natural History, and capital examples of the white kaolin surrounding the unaltered orthoclase were found at Fourth Ave. and 77th St., also at 43d Street and First Avenue.

The granite where it occurs in large developments, as at 48th to 55th Sts. and 10th Avenue, has an industrial value for foundations, but more generally it is a vein stone of no consequence, a mere geological incident.

FOLDS AND PLICATIONS.

Perhaps the most suggestive features in connection with the rocks and geology of Manhattan Island are the remarkable dislocation, crumpling folds, and angular plications of the gneissoid rocks, a disturbance in which the granite veins seem to have participated or which indeed it would seem in many cases was itself the cause of these secondary or intrusive volumes. These folds vary from wave-like arches, with an amplitude of inches or several feet, exhibited sometimes in delicate ripple-like curves or in broad folded zones, or in sharp roof angles when the compressed beds are flattened almost into verticality. In many cases the outer or surface

Fig. 2.—Riverside Drive and 93d St., north side, in process of removal, showing granite vein crossing quartzose gneiss.

crests of the arches have been weathered or planed away, and the dome is not seen but only the inclined convergent layers of rock. These folds are almost invariably steeper on one side, viz: are pushed over, and the occurrence is noted of the fold being thrust violently over, so as to assume horizontality. These minor examples may be considered magnified and carried to their extreme geological consequences in the ridges of the island, the north and south folds which represent its present relief, and are the heaping up, through contraction of extended beds: a contraction slowly inaugurated and, perhaps, slowly achieved, but marked by intermittent periods of extreme dynamical intensity. Such folds are seen in the Transverse Road at 79th St. and Central Park, formerly at the east end of Washington Bridge, while they are shown in the most wonderful confusion at 152d St. and Seventh Avenue. For a block on either side the eye traverses a face of distorted gneiss, with contracted bands of alternating feldspathic, micaceous, hornblendic rock. The strata, as a whole, lifted up in a line of double curvature, are standing almost "on end," slightly inclined eastward, while subordinate wrinklings, twistings, kinks in endless profusion, convert the surface into a "living picture" of primary forces crumpling the earth's crust, as the hands might flex and crush a bundle of paper cards. It seems probable that the minor small waves of plication were produced before the final uplift came which crowded these into up and down shortened bends. (Figs. 7, 8, 9.)

These facts and suggestions bring before us the problem of the origin of this whole group of rocks. They sharply interrogate our explanation of their occurrence. Without starting out with the most simple assumptions of geology, or involving this sketch in a

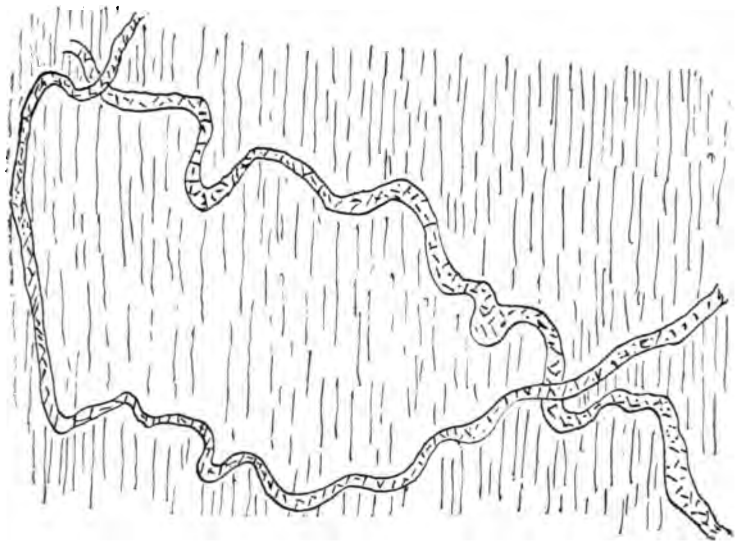

Fig. 3—Granite veins, 77th St. and 10th Avenue.

rudimentary classification of rocks, it is usually agreed to regard the crystalline schists to which these gneisses of Manhattan Island belong, as originally sediments, or the accumulation of ancient muds, mingled doubtless with detrital matter that was not mud, but sand, both of quartz and other silicates; the whole was derived from the wear and tear, the attrition and slow degradation of still older rocks, perhaps, in the case of this island, those granulytes and highly siliceous and ferruginous rocks which form the Highlands.

However accumulated, these beds of sediments represented a heavy deposit of which silica, alumina, iron oxides, lime, magnesia potash and soda, and more rare elements were parts, and it was a change of hardening, solidification and chemical combination which slowly ensued, and under the auspices of certain physical conditions created these beds of rock, now so familiar to us, and yet, in some respects, so difficult of interpretation.

Heat from pressure, heat from mechanical movement, static heat (the interior heat of the earth), the friction of the beds over each other, pressure from the crustal shortening, pressure from superincumbent masses of sediment brought about a sort of fusion of the whole, in which vapor of water at high temperature was disseminated. The mud, silt and sands were thus brought under mineralizing agencies which slowly formed the various silicates now represented by the micas, feldspars, hornblende and associated minerals, the unequal and varying contents at different points mak-

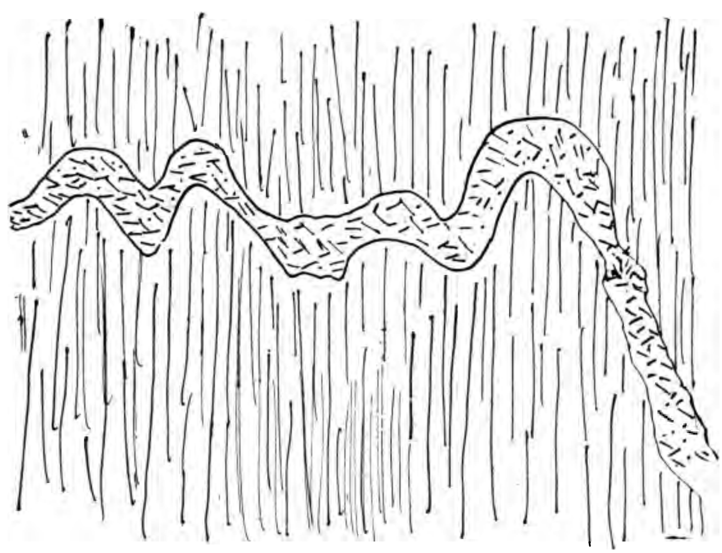

Fig. 4.—Granite vein, 1-3 feet wide, 78th St between 10th and 9th Aves.

ing different local products, as the garnets, where lime prevailed, tourmaline, where iron and borax chanced to be, sphene somewhere else, where there was titanium, cyanite, beryl, oxides of iron, columbite, and all the rest, according to such aggregates, as, obeying chemical affinities, the deposits warranted.

Not, indeed, that this explains everything, for one of the mysteries of rock and mineral making is, that very similar chemical conditions produce now one sort of rocks or mineral, now another, and why, is not easy or possible to determine.

This action, we have described, was metamorphism, and it seems most probable that the *conformable* (see *ante*) granite veins were formed with the schists and gneisses. In Brittany, in Central France, in Scandinavia, in Germany, in Canada, granite veins, or seams, are interstratified with gneiss, or mica schists, and appear contemporaneous. Granites vary greatly in composition, the percentage of silica (quartz) being variable and thus changing the relations of the other elements. The coarse and fine granites on Manhattan Island suggest naturally differing conditions, as perhaps slower crystalization in the case of the former, though it also seems that chemical composition has something to do with this contrast of texture.

Now the whole extent of beds was in the process of this compression and fusion, flexed, bent and broken. There were

Fig. 5.—Large garnet from vein in West 35th Street, half diameter.

wrenchings, overturnings and refusions; in fact, after the beds had assumed partial or complete mineral stability, the subsequent movements evoked the more violent strains, and the rubbed, triturated and parted surfaces gave rise, under the irresistible contraction, to new fusions which spread and penetrated through the crevices; these later movements themselves originated and, in the opinion of the writer, created the secondary granite veins which cut across the gneiss, as well as many interlaminated streaks and strips of granite. Not, indeed, that the granite veins were intrusive, in the sense that they were filled from below from deep seated magma, but that they represent refused gneiss which, along the openings and shearing faces, re-crystallized as granite. (Fig. 10.) This is possible, as the chemical composition of granite and gneiss are practically identical, and both exhibit an almost equal latitude of variation. The gneiss on Manhattan Island runs through quite a range of variation, here feldspathic and there full of quartz, and again normal or micacaceous.

Segregation has usually been assumed as the explanation of these granite veins, by which is implied, a gradual solution of the mineral contents of the gneiss in heated waters, and their redisposition as crystals of feldspar, mica and quartz, forming granite in veins and openings. But there is no evidence of such solution; no vesicular or cellular structure anywhere in the gneiss in the neighborhood of these veins whence the granite menstruum was obtained, and the even straight edges of some veins seem to preclude the idea of solution which would have acted unequally along the

Fig 6.—106th Street; entrance to Central Park.
Showing decomposing granite vein in schist.

vein margins. This latter stricture may, however, be cast aside as the boundaries of the conformable veins are by no means always straight and those of the cross cut veins seldom, but this fact is as consonant with the theory of dynamic fusion as with chemical solution.

Amongst the many interesting evidences of disturbance an easily reached example is in 110th St., west of Columbus Avenue. (Fig. 11.) The wrinkled and twisted lines of bedding are most extraordinary along this section; hard, dense bands of hornblende gneiss, alternating with a looser mica-schist, or gneiss, are folded into complicated figures of vertically undulating streaks, and with *ovethrusts* where the flinty looking hornblende gneiss is wrapped up in sheets of mica rock, while strings of quartz, intercalations of granite, with quartz knobs and insertions, produce an almost damasked surface in its variations of structure. On the south side of the street the aspect of the twisted beds is even more instructive. There are portions of the rock which seem saturated with quartz that, in excess of all possible combinations with bases, has been expelled in strings of crystalline nodular quartz, while granite veins, streaks and inclusions dot and, as it were, stream down the wavy and crumpled faces of the mica schist. It tells in unmistakable language of extreme compression, of the rolled up and smashed strata, and it seems even to express more legibly a period of partial mineral fluidity. Not, indeed, that there is seen here flowage, or that the

Fig. 7.—152d St., north side, between 7th and 8th Avenues. Showing East dip, and contorted and deformed strata.

lines of rock become chaotically mingled in currents and streams, but there has been plasticity and movement and, if the language can be pardoned, a secretive action by which the granite and quartz have at joints, crevices, openings, pits, or loculicidal slippings, formed within the gneiss itself.

There is, perhaps, on the island nothing more extraordinary and instructive than the sectionized hill at 152d St. and the Central Bridge mentioned above. This exposure would repay a dozen visits of inspection. If ever rocks spoke, they speak here.

As demonstrating a series of disturbances, or shocks of compression at different times, the faulted veins of granite seem significant, though, as remarked by Mr. Stanton, these are infrequent. One in 87th St., not seen by me, but noted by Mr. Stanton, offered an instructive example of faulting, and the intersecting veins seen at Mt. Tom (Riverside Drive and 83d St.), seem helpful in establishing a diversity and a distinction of movement.*

At what time these changes, which folded the rocks and lithified the sediments began, can with no certainty be established, though it was certainly long subsequent to their deposition, and continued intermittently afterwards. It was, perhaps, at first, gradual, progressive and gentle, and only after the strata had assumed solidi-

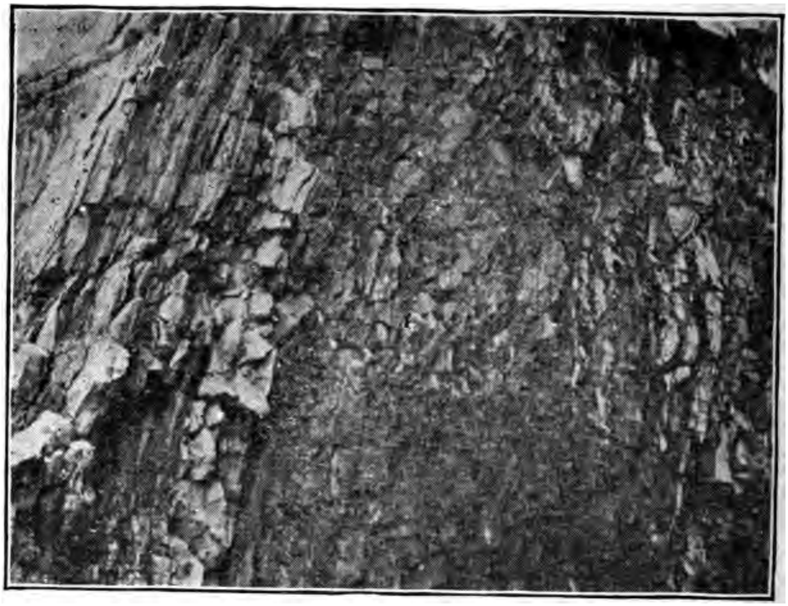

Fig. 8.—152d Street, south side. Close study of rocks, showing east dip and bedding.

fication, and offered greater resistance, was it accompanied by ruptures and fissuring. The beds on Manhattan Island as seen today indicate much flexibility. The period of mountain making is usually fixed at the close of the Lower Silurian and the end of the Paleozoic, and we may for reasons of conformity consider these folds to have been inaugurated in the former period.

In connection with this it is appropriate to emphasize the ***anticlinal*** axis on the west side of the island and the synclinal on the east. The beds on the west side have been rolled up into arches which later pressure has flattened into vertical plates, and those on the

* On the pyramid rising from the sward in Riverside Park immediately south of Mt. Tom is a wide vein of granite, granular for its greater extent, on either side, but holding a differentiated centre of coarse pegmatitic granite, as a vein core. There are here some undulating and twisted cross veins of granite.

east curved downward into valleys or troughs. The area of distortion, strain and crumpling is lifted more into view on the west, and is depressed more out of view on the east. It has been remarked that the granite veins are more numerous on the west side of the Island (Fig. 12), than on the east, and this might be expected if their origin is connected with this violent dislocation of the rocks. It would also be reasonably expected that the consequences of distortion would be shown more deeply seated on the east, below the crown of the synclinal or trough, and that granite veins would be found at great depths.

The crucial question of the age of this complex of gneiss and granite is a trying one. *Without circumlocution it is believed by the*

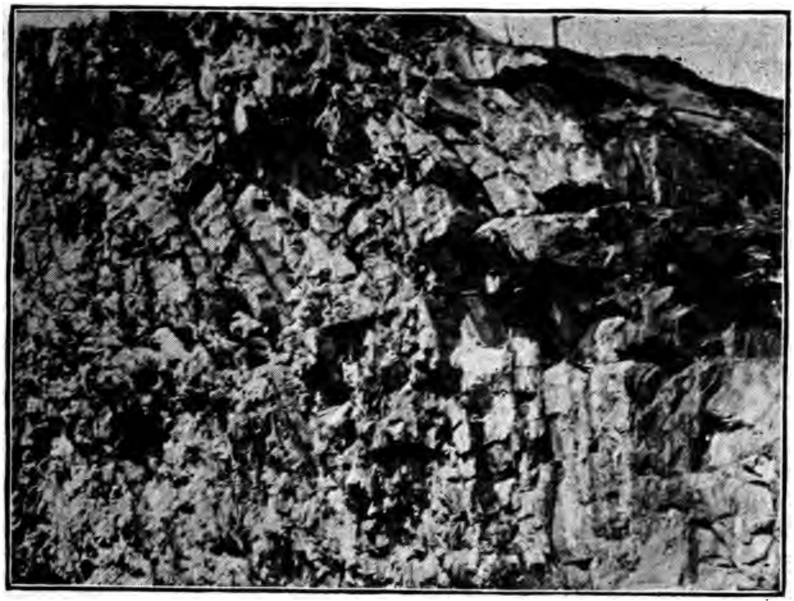

Fig. 9.—152d St.; north side. Close study of rocks, showing flexure.

writer that these beds are Archaean, and that the limestones are to be included, but it also may be instantly admitted that the weight of authority is against this view.

SERPENTINE.

The serpentine area of Manhattan Island is a very limited one in comparison with the occurrence of this rock in Jersey City and on Staten Island (see Borough of Richmond), and it is mingled with calcite, forming a blotched green and white rock known as *ophio-calcite*. Some years ago I examined this locality and prepared a short paper on the subject from which an extract will sufficiently indicate its extent, character and origin.

"A bed of serpentine rock bordering the western margin of New York Island, between 55th St. and 60th St. and now for the most part built over, some years ago awakened a momentary interest from its display of strips of ophio-calcite which resembled the eozoonal (see Dana under Laurentian) beds of Canada, and led to some surmises as to their organic character. This area of serpentinous rock, forming a band enclosed on the west and east by mica schists, or a highly micaceous gneiss, and limited southward by a broad outcropping of granite, is gradually disappearing from view and may at any time become an affair of local record. At present its best exposure is on the north side of 59th St. between 10th and Eleventh Avenues, and it can be traced to near

Fig. 10.—126th St., north side, a few feet west of Manhattan Ave. — showing granite vein and shearing.

56th St. by isolated knobs appearing above the level of the sidewalk and in back yards. It was recently uncovered to some extent when the cisterns for the immense gas-holders of the Equitable Gaslight Company were being constructed, and some examinations were then made, both of the rock in place, and in microscopic sections.

"This outcropping of serpentine is intimately associated with and intermingles with an acicular, fibrous, partially altered hornblende or actinolite, the hydrous anthophyllite of Dana. From this area were derived the numerous boulders of this rock, which are found to the south as far as the northern margin of Long Island. Dr. L. D. Gale describes this anthophyllite locality, saying: 'the *rock varies considerably* in character in different places where it has been uncovered, and occupies a series of conical hills, some five or six in number, distributed in a northerly and southerly direction. In some places, as at 60th St. it is talcose in structure, and may be split into thin slabs; in others it is dark gray, almost black, composed of straight fibres, arranged in a columnar form, meeting and crossing each other frequently at right angles.' He further says: 'It is remarkable that the granite lying on the west and the gneiss on the east of the rock in question, come in complete contact with it without intermixing, So remarkable is the line of separation on the side next to the gneiss, where there is the best opportunity to examine the two, that within the space of three inches, each rock possesses all of its own peculiarities with none of those of its neigh-

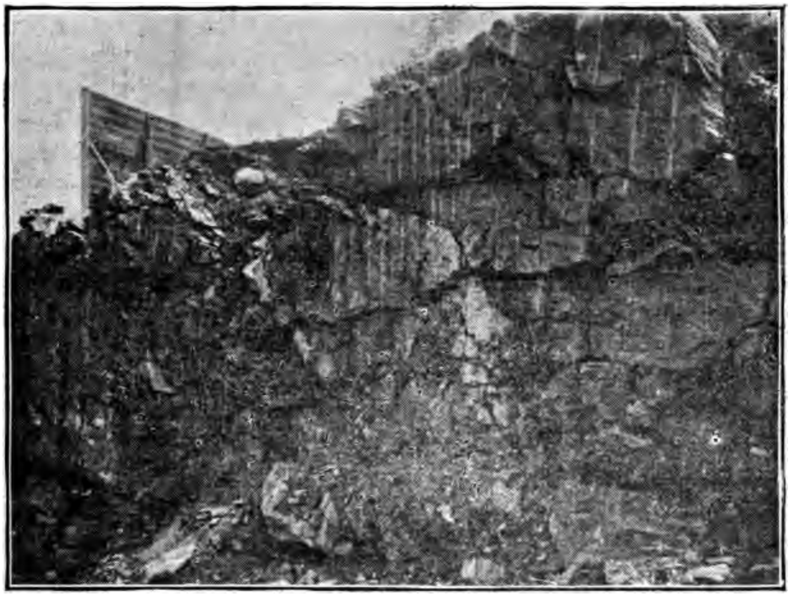

Fig. 11.—110th St., south side, near Columbus Ave., showing folded granite vein in very micaceous gneiss. (The vertical lines are drill holes.)

bor.' In speaking of the serpentine, he says: 'In the same vicinity are found masses of serpentine and limestone, intermixed, exhibiting a porphyritic appearance; the serpentine appearing green and the limestone white.' This refers to the eozoonal-like portions, which would seem, so far as their macroscopic (in hand fragments) appearance goes, to easily warrant their reference to a close relationship with the Canadian rock containing that debateable organism.

"Cozzens, in his Geological History of Manhattan, or NewYork Island (1843), p. 12, refers to this locality, saying: 'Between 54th and 62d Sts. the shore and Tenth Ave. there are four or more small knolls of black serpentine, with scales of silvery or golden talc, accompanied by a vein of anthophyllite about twelve feet wide.

This vein is in a vertical position. At the north end of the serpentine proper, this anthophyllite shows itself in two places, *in place*; one on the rising ground and near the sienite, the other at high-water-mark on the shore. Actinolite is found imbedded in the anthophyllite. The serpentine locality commences where the granite ends. At the south end there is a vein of carbonate of lime. This carbonate of lime has many small specks of serpentine diffused through it, and forms a kind of 'verde antique' which, when polished, makes handsome specimens.

"These early observers speak of the association of the serpentine with hydrous anthophyllite, and this association points significantly to the origin of the serpentine itself. This bed of serpentine is, in all probability, an altered amphibole, or hornblende schist, and the 'porphyritic' 'verde-antique' eozoonal portions, the products of such, are alterations produced under conditions of strain and pressure, accompanied by aqueous infiltrations. I have not seen the vein of anthrophyllite alluded to above, but on visiting the locality on 59th St. where a ledge rises up in a mound-like prominence I found anthophyllite in masses, apparently recently blasted and removed from their beds of place with which was seen actinolite largely changed to serpentine.* An examination of the hill

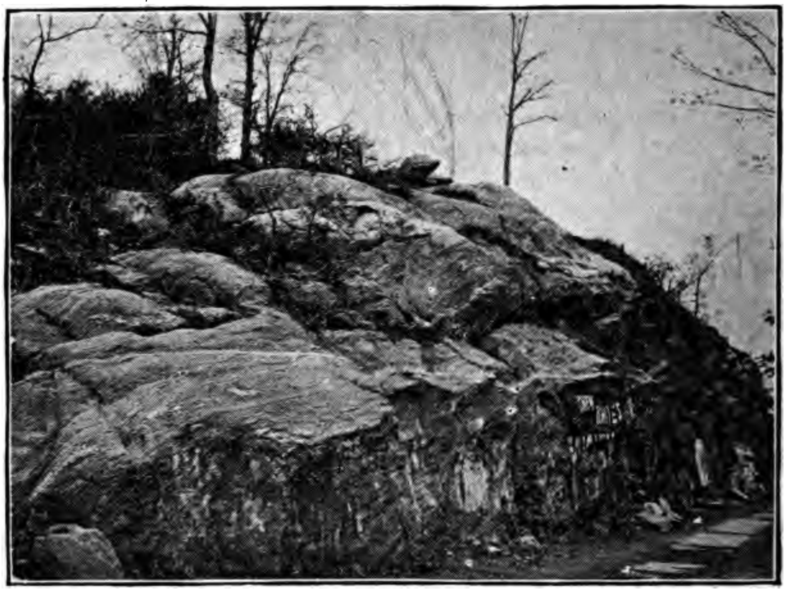

Fig. 12.—Manhattan Ave. and 126th St. Showing gneiss and veins and patches of granite.

Mr. A. Woodward has recorded his observation of Actinolite changing to hydrous Anthophyllite at 142d St. across the Harlem river and in a cellar at 49th St. (presumably near the river). *I have not seen specimens* from either locality.

showed a vertical face where eozoon structure (ophio-calcite) was seen at a number of points. It appeared in seam-like bands, expanding in some spots and contracting at others, forming an irregular scattered prolongation of parts, varying in grain from fine to coarse, the former accompanying an apparent flexure, or contraction of the original stratum. On the south side of 50th St. where the excavations were being made (mentioned above) an exposure of the serpentine bed was accessible, where the ophio-calcite was seen frequently presenting a seam-like appearance, contracting to narrow bands and again developed in broader sections, while sometimes it sporadically occupied nests in spots enclosed in the surrounding rocks. Away from these parts the serpentine was fibrous or micaceous."

[Note.—The ANTHOPHYLLITE, SERPENTINE, EOZOONAL sections, referred to above, can be seen and examined by the teachers at any time in the collection of New York Island Rocks, and in the Mineral Cabinet of the American Museum of Natural History.]

Serpentine has been found in connection with the dolomite of the island, as at Lexington Avenue and 123d St. Anthophyllite and actinolite boulders have been found south-east of 59th St. locality at Corlear's Hook and on Long Island.

It is altogether probable that a short range of low hills having some genetic connection with those of Hoboken once occupied a part of the western margin of Manhattan Island at about 59th St. that they have been chiseled away; that for some reason they were especially vulnerable to the attacks of the ice sheet, and that their eroded foundations have now only the single visible witness in the low mound near Eleventh Ave. Dana regards this serpentine locality as related to the limestone areas in Westchester county in which serpentine is known to occur.

HORNBLENDE ROCKS.

The Hornblende rocks of Manhattan Island are not numerous but are apt to arrest attention by their dark color, which varies from a dark green to black. The hornblende rock, when examined by a hand glass, is seen to be composed of flattish blades of hornblende crystals closely appressed together in its more open textures, while it grades into a really dense and hard fissile slate-like rock, now not often encountered. It occurs interbanded with the gneiss, and yet rather sharply separated, the mica-schist or gneiss seldom showing any scattered or attenuated evidence of the hornblende along the edges of the latter. Hornblende (classed under Amphibole) is a silicate of alumina, iron, magnesia and lime, and if we regard these hornblende beds as originally sediments subsequently metamorphosed, they represent layers of ferruginous and calcareous clays.

They have, indeed, been regarded as possibly intrusive dikes of igneous rock, which have undergone alteration.

The hornblende gneiss, a flinty looking rock, composed of hornblende, mica and feldspar, is not infrequently met, as at 122d St. and Harlem Heights; at 94th St. between 4th and 5th Aves.; hornblende schist, with crystals on the surface, at 80th and 81st Sts. and Ninth (Columbus) Ave. now built over; hornblende gneiss, with quartz veins at 116th St. and Columbus Ave. hornblende gneiss penetrated by the Aqueduct shaft at 165th St.and Amsterdam Ave.: at 190th St. and 10th (Amsterdam) Ave. here enfolding garnets; schist with scapolite, at 93d St. and Lexington Avenue.

The hornblende rocks may represent iron sediments; there is a large percentage of iron in hornblende, and as Dana remarks, "the iron of those sediments went, for the most part, at the time of *metamorphism* to make the black, iron-bearing mica, or hornblende, the rest of it entering mainly into pyrite and, sometimes, garnet. * * * * * * Hornblende has been formed where iron existed without enough of potash for making mica."

The rocks of Manhattan Island teach the lesson of *metamorphism* everywhere, and the teachers must endeavor strenuously to acquire a keen realization of that remarkable geological process. They have otherwise missed the great lesson the rocks of New York convey.

The hornblende beds of New York Island, if interpreted as intrusive dikes, are still examples of metamorphism. The structural character of the original plastic eruptive rock has been changed, and the heterogeneous crystalline mass become altered to a schistose felted stratum of hornblende. The connection of schists with original masses of diorite, gabbro and diabase was pointed out by Lehman. Jukes, indeed, suggested long ago that hornblendic and augitic lava and tuff may be metamorphosed into schists.

As accentuating the metamorphic character of the Manhattan Island beds it has been insisted, that as we pass northward the crystalline schists are gradually replaced by slates. These slates are Hudson River beds, and their correlation with the Manhattan schists, makes the latter of the same age. This is called "Progressive Metamorphism" and has been illustrated in the Dalradian sediments of Loch Arne in Scotland and the archaean nucleus of Saxony.

THE LIMESTONES.

In the third topographical section of Manhattan Island, that extending from 110th St. northward to Spuyten Duyvil where the narrow and elongated ridges swell upwards to Washington Heights and Fort George and the Limestone hills at Kingsbridge we have three features of geological interest, the limestone beds themselves, the transverse ravines or passes at 125th St. to 130th St. and at Inwood, and the wide flat alluvial-drift plain known as Harlem Flats.

The limestone beds attain an elevation of about fifty feet along the Ship Canal and in the cut as well as at the opening of 200th St. (Fig. 13), and in a few deserted quarries are fully displayed. It is a glistening crystalline limestone weathering to a fine sand. It extends from the village of Marble Hill southward to within 300 ft. of the little church at the entrance of the Inwood

Fig. 13.—Limestone beds, 200th Street, west, showing dip to the Kingsbridge road.

ravine or Dyckman St. On the west it abuts against the gneiss. It extends east, north and south under the low valley from Spuyten Duyvil Creek to the bluff surmounted by Fort George where its contact with the gneiss is hidden by a great depth of drift.

The limestone exhibits its various characters along the wall south of the Seaman Mansion where the coarse crystallized surfaces are contrasted with very fine-grained and schistose rock. The view from the heights of Spuyten Duyvil is instructive. The dome of limestone is plainly seen, sinking on the west into a valley or crevice, penetrated, a little way, by the Spuyten Duyvil Creek, whence rise the steeper and higher walls of the Inwood spur of gneiss. The limestone formation is characteristic, being undulating and softened into low swells by erosion and solution. The dip is east.

At the extreme western end of the Spuyten Duyvil Creek, the opening to the Hudson River suggests a crack, fault, or fissure, but east of this, at the cut of the railroad, (Fig. 14) the line of the creek seems to mark the delimitation of the limestone on the south from the gneiss on the north, and the creek has its bed in limestone, as the streams generally do in Westchester Co., (Dana). A dominant point of interest from which the topography of this section is well descried is at the end of the Bolton Road leading up from Dyckman St., and beyond the House of Mercy, before the descent is reached which plunges in Spuyten Duyvil Creek. In

Fig. 14.—R. R. cut through gneiss hill north of Spuyten Duyvil Creek.

the aqueduct shaft, at 180th Street, between 10th Avenue and the Harlem River at 165 feet below the bed of the river, at its centre, or 465 feet below the level of Tenth Avenue, coarse and compact limestone was taken out

This limestone underlies the Harlem River and is produced in long prolongations underneath Fourth and Fifth Avenues, (at 132d St.,) and also under Eighth Avenue, interrupted by gneiss, which appears to hold it in synclinal troughs, while in Westchester Co., both at Westchester and Eastchester villages and at Mott Haven, Morrisania and Tremont it is found, and is, thence apparently ivergently produced, being noted at Sing Sing, Sparta, Dobb's 'erry, Peekskill, Verplanck's Point, Tarrytown and Whiteplains.

Prof. Dana, in a series of elaborate observations, has under-ıken to bring this Manhattan limestone into structural continuity ·ith the Taconic marbles and schists, or that range of metamor-hosed rocks which reaches northward through western New Eng-ınd. He would thus assign a Lower Silurian or *Ordovician* Age › the Kingsbridge rock. The evidence does not seem all exhausted et, but there is a growing inclination, at least, to give these lime-:ones a possibly lower place in the geological column than the rest f the island, making the *Manhattan schists* Hudson river. (Fig. 15).

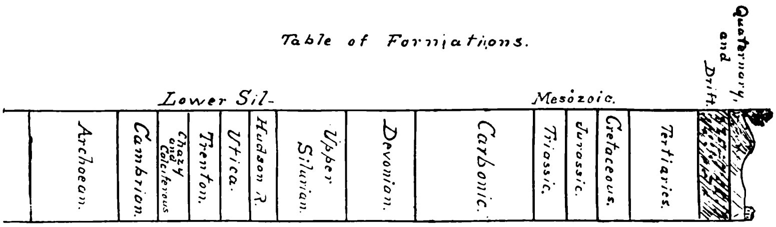

Fig. 15.

The assumption that the limestone is later than the gneiss ıight seem quite controverted by the facts that first, the limestone ı its southern prolongation at Third and Fourth Avenues, and at ›ixth and Eighth, is so intermingled with the gneiss as to become :self schistose or laminated—a sort of gneissoid limestone—or, to ead the inferences inversely, the gneiss has become so calcareous s to appear a limestone; and, secondly, the observation made by ›tevens and apparently repeated by Kemp, that at Third and Fourth \venues the limestone is interbedded with two strata of gneiss, ›ne above and one below; and again by Stevens, that at Sixth \venue in West 132d Street the limestone is thrown upward in an ırch with "the gneiss reposing conformably upon it;" all of which :onditions would plausible argue a contemporary origin for both ;neiss and limestone.

As to the second group of facts (?) there are some doubts ›ermissible as to the construction given to the relations observed, nasmuch as at some points, at least, the limestone overlies the ınderlying gneiss; and, as to the first, the intergradation of gneiss ınd limestone, two sediments collected at widely separated periods vould, at some subsequent moment, when metamorphism, folding ınd compression began, be, at much of their surface of contact, hrust into each other, and become insensibly but thoroughly min-·led. Indeed, Stevens avers that "the thrust of large masses of mestone into the solid gneiss was seen, crushing and grinding the .tter as it passed, showing that the rocks were hardened when the ›lding action took place and the thrust was made."

As to the interstratification of gneiss with limestone noted by Dana, sediments that would form gneiss might naturally have accumulated through the limestone and formed beds within it. It would seem that the large masses, however, of gneiss (certainly the Fordham beds), underlie the limestone, and are older. Inasmuch as the calcareous sediments and the aluminous sediments were changed to rock at the same time, and as that time was long subsequent to their first deposition, many beds of aluminous material much later than the first, might, indeed have formed over or in the calcareous deposits. Metamorphism practically gave all these aluminous sediments the same character, though they might be widely separated in age. The contention of authors is that the great bulk—the beds of the Manhattan schists—overlie the limestones and are of a different age.

The argument to raise the geological position of the Manhattan Island rocks has been pursued with great earnestness by Dr. F. J. H. Merrill of the State survey, and following the lines of research opened by Prof. Dana, he has from stratigraphical (the relation of the rocks in reference to the succession of beds) considerations, urged the separation of the gneisses from the Highlands southward into three groups (Borough of the Bronx), one overlying the limestone. The limestone is made Calciferous-Trenton, (see ante Fig. 15), the Manhattan schists, Hudson River, and the Fordham and Yonkers gneisses archaean.

The limestone of Kingsbridge, as shown by Kemp, is a magnesian limestone containing a little over twenty-one per cent. of magnesia and is not a true dolomite. Mr. E. C. Eckel recently discovered a point of contact between the Inwood limestone and the Manhattan schists which seemed clearly to show that the latter at this point overlay the limestone beds.

The two transverse depressions at Manhattanville and at Inwood, which are features in this third topographical section of New York city, have been regarded by Prof. Dana as the results of an oblique wrenching of the rocks, or a sort of lateral pull which has at these points separated the ridge and permitted the agencies of weathering to effect the widening and reduction of these initial crevices. It is evident also that they have been former passages for the current of the Hudson River to pour through eastward. To-day a lowering of the general level of the land forty feet would bring these passages into tidal communication with both the Hudson and Harlem. There are evidences in both that they have been the channels of ice movements and the alluvial or detrital plains into which they enter, the Hudson flats on the one hand, and the upper basin of Harlem River from Marble Hill to Morris Docks on the other, have originated in fluviatile motions through these gateways, fluviatile motion which has modified drift deposits previously accumulated in these hollows. The Spuyten Duyvil Creek is considered a possible third break in the rocks, and is far more irregular. It has been called by Stevens a "cross fracture," and forms now a picturesque gorge.

WATER-WAYS.

The island is limited to the west by the Hudson, which has cut a deep gorge in rocks presumably gneissoid in character, but which Stevens hypothetically considers limestone—an unlikely supposition. This gorge has been filled up by a stiff, tenacious clay-like silt holding recent fossils, as the common blue crab (*Callinectes hastatus* Fab), and such shore shells as (*mactra*) *lateralis* Say.

On the east the island is bounded by the continuous channel of the Harlem and East Rivers, the upper portion of which, that north of Fort George, is cut in limestone. This portion is bordered by low banks which widen into a cirque-like area which was probably an expansion of the Harlem River which has now withdrawn into its present and marsh invaded bed. This immediate region has been elevated and depressed, and the accumulations of various deposits in descending layers furnish records of their character. Marsh land and river mud and forest beds with sandy zones tell of its mutations.

The most important disclosure made in this region was the discovery in November, 1891, during the excavation of the Harlem Ship Canal, at the end of Dyckman's Creek, of the tusk of a mastodon three feet long and seven and a half inches in diameter. The order of succession above this fossil from the surface was salt meadow, meadow, sod and silt, filled with roots of meadow grass four to six feet, below a deep bed of incipient peat twelve feet, sands and clay eighteen to twenty inches and at the bottom dolomite upon which the clay rests. The peat contained "quantities of seeds, apparently carices or sedges and grasses, as well as a few nutlets of some bush or shrub not yet determined, and examples of the elytra of beetles. At the top of the peat occur numbers of the stumps and roots of forest trees and fragments of wood. No evidence whatever is found of any marine substance below the roots of marsh grass; not a vestige of any kind of mollusks, marine or fresh water can be detected, although now living and abundant in the salt water at the surface"—(R. P. Whitfield).

Dr. Merrill insists that much of the so-called clay associated with these limestone beds, which are so generally river valleys in Westchester county, is the result of the solution of the limestone itself which, losing its lime, leaves behind a mass of "aluminous and magnesian material, whitish, green with scales of prochlorite, red with peroxide of iron, and sometimes black with separated carbon."

The Harlem River turns east below 155th Street and moves over gneissoid rocks, probably in a shortened synclinal trough now largely floored over with clay-like mud.

DIPS AND STRIKES.

The entire thickness of the gneiss and schists on Manhattan Island may be, perhaps, one thousand feet—of the limestone six hundred to eight hundred feet.

The Strike, (viz: the compass direction of the axis of a ridge, chain, or cordillera) in Manhattan Island is very near the direction of the avenues, N. 35° E. Dr. L. D. Gale made seventy-five observations of strike, of which fifty gave results varying from N. 25° E. to N. 35° E., making the medium strike N. 30° E.

The Dip, (viz: the inclination to the horizon of a group of beds) is generally west, averaging within ten degrees of verticality. On the west side, especially from the city to Harlem valley, it is generally vertical, and also as far east as Eighth Avenue, but on the east side from Fourth Avenue to the river the dip is irregular, varying from 45° W. to 45° E. The violence of the compression of the originally horizontal beds has practically brought them now, as seen, in an upright position.

GEOLOGICAL RETROSPECT.

The Island of Manhattan is a gneissoid ridge, modified at its northern limits by limestone belts, and carrying over its surface an accumulation of detrital matter in the form of sands, clays, gravels and unassorted debris. Its initial stages were water-deposited sediments, the waste of some continental area north of it, together with the formation of limestones by living organisms. Its later stages—the process of lithification, or metamorphism—by which these sediments became schists and gneisses and marbles, with an accompaniment of physical alteration carried these flat deposits upward into almost vertical sheets, sundered and cracked them and refilled the fissures with granite, which may have been the more slowly crystalizing—or crystalizing under less pressure—fused gneiss, or, in some cases, injected veins.

Except as it underwent denudation and was raised or depressed by secular movements of the earth's crust, it apparently was not further changed by any later rocks being laid down upon its primitive gneisses and schists. As the Ice Age passed, it left it covered with drift, and it may have been during a subsequent elevation that the conditions imagined by Dr. Newberry supervened. For the interesting picture is presented of the Hudson River finding its exit into the Atlantic ocean some hundred miles from its present debouchment in New York harbor at a time when the New York harbor was only an incident, a slight expansion in its course seaward. Manhattan Island was then a far higher wall on its east side, and the Palisades a loftier escapement on the west, and it received as an eastern tributary the waters of the Housatonic draining the water-sheds of Connecticut, and itself passing between high-wooded banks, encircling the raised promontory of Governor's Island, and mingling its tides with those of the Hudson along the shores of Ellis' and Bedlow's Islands, which were then united to the mainland. Further south at the opening of the present channel of the Kill von Kull, the Passaic swollen by the waters of the Hackensack united its flood with the two rivers, and the combined volumes of water swept past Staten Island through the Narrows outward to the distant edge of the continent, where, to-day, eighty miles from the present shores, the floor of the coast-plain sinks steeply to the abysmal depths of the ocean.

The considerations which support this surprising view are based upon the well known facts of the Hudson River's deeply eroded bed. Its bed lies in the older rocks, and the gorge through which it once flowed is indicated to-day by a submerged fissure now greatly filled up with sediments and transported clays. These deep canyons were cut in pre-glacial days when an immense drainage area north and east, pouring its waters through the also deeply excavated river-course of the Mohawk, formed, by the way of the Hudson, the avenue of its escape to the sea. The land must then have been greatly elevated to have permitted the attrition over the now buried rock channels, which was necessary to chisel out and remove, by descent, their resisting, but slowly loosened and abraded layers. From these ascertained conditions this re-construction of the very remote topography of this region is made, and how it assumed its present aspect, and grew into the configuration it now has, which fits it perfectly for human occupancy and industrial expansion, may be told in Newberry's own suggestive sentences: "After the lapse of unnumbered ages, during which this nook among the hills was slowly prepared for the important part it was to play in the history of the yet unborn being —man—a quiet subsidence of the land or elevation of the water begun in this region. Gradually the sea flowed in over its shores, crept up the valleys of the streams checking their flow and converting them into tide-ways until it washed the base of the Highlands. Up to this time the surface of the littoral plain in its gradual submergence formed a broad expanse of shallow water bounded by a monotonous line of beach, with no good harbors—a shifting, dangerous shore, such as is most dreaded by mariners. By further subsidence, however, the water flowed up into the valleys among the New York hills, and into the deeper river-channels, making of the first, safe, land-locked harbors, of the second, navigable inlets or tide-ways. In this manner were produced the magnificent harbor and the system of natural canals connected with it, which determined the position and created the subsequent prosperity of the commercial emporium of the New World."

LITERARY DIGEST.

In 1816, Hayden, in the Geological portion of Prof. Cleveland's Mineralogy " describes a granite ridge crossing New York Island and appearing at Hurlgate on Long Island, thence extending into Connecticut." (Stevens).

Wm. Maclure, in his famous Geological Map of the United States, puts down New York Island as " primitive formation."

S. Akerly, in 1820, published " An Essay on the Geology of the Hudson River, and the adjacent regions; illustrated by a geological section of the country from the neighborhood of Sandy Hook, in N. J., northward through the Highlands, in N. Y., towards the Catskill mountains." He speaks of the southern portion of the island as alluvial " on a granitical base," appearing at the Battery. His reference to the serpentine rocks is of interest. He writes " Rocks, in which magnesian earth predominates are frequently found, though not in large masses, but mostly in detached pieces. Some of these are steatites, some serpentines, and others asbestos. Many elegant specimens of steatites may be procured; some of which have handsome dendritical appearances upon them." He alludes to the limestone at the north, and speaks of *granatines*, *granitelles*, *granilites*, *gneiss*.

In 1839, Dr. L. D. Gale published in the Geological Report on the First District of the State of New York a very accurate study of the region of New York Island.

In 1840, Prof. H. D. Rogers, in a Geological Report on the State of New Jersey, separated the rocks of the Highlands from those on Manhattan Island.

In 1843, W. W. Mather, in the Geology of the First District of N. Y., discussed the geology of Manhattan Island.

In 1843, Issachar Cozzens, Jr., published his " Geological History of Manhattan or New York Island," a book of much interest, discernment and reminiscent entertainment. Therein he discusses the Palisades, Hoboken and Staten Island. Many colored plates and map.

Prof. R. P. Stevens, in 1865, read his report upon the " Past and Present History of the Geology of New York Island," before the Lyceum of Natural History. In this he assumes a limestone *bed below the* channel of the Hudson River.

Dr. H. Credner, the distinguished German geologist, has written a paper "On the Geology of the Vicinity of New York City," published in 1865, in Germany.

Prof. J. S. Newberry contributed, in 1878, to the Popular Science Monthly, a very readable paper, on "The Geological History of New York Island and Harbor."

In 1887, Prof. J. F. Kemp read his admirable, and conspicuously pre-eminent, contribution before the New York Academy of Sciences, under the title, "The Geology of Manhattan Island."

During 1880, 1881, 1882, Prof. J. D. Dana contributed, to the American Journal Science, an important series of papers on "Limestone Belts of Westchester Co.," in which he very explicitly and intimately determined the limits of the Kingsbridge limestone on Manhattan Island.

In 1890, Prof. F. I. H. Merrill discussed, in the American Journal Science, the "Metamorphic Strata of South Eastern New York," which, in 1896, was succeeded by a paper, somewhat skeletonized, on the same subject, and a longer paper on the "Origin of Serpentine," both published in the New York State Museum Report of that year.

In the February No. (1899) of the American Geologist, Mr. E. C. Eckel published an article on "Intrusives in the Inwood Limestone of Manhattan Island," wherein he described a locality at the northern end of the island, a few blocks north of Fort George, at Hawthorne Street, between Maple and Sherman Avenues, where the limestone is cut by a pegmatite or granite dike giving rise near the contact to tremolite, biotite and tourmaline.

MINERALS OF MANHATTAN ISLAND.

Ten years ago, and continuing since, with alternately relaxed and renewed interest, the collecting of the minerals of New York became a very significant passion amongst mineralogists. The nature of the island's rocks, their metamorphic origin and their intersection by granite afforded a speculative basis for very flattering expectations. The results have not disappointed these hopes. The number of separate mineral species on Manhattan Island are about ninety, and in many cases the specimens have proved of surprising beauty.

L. D. Gale, I. Cozzens, B. B. Chamberlain, D. S. Martin, S. C. H. Baily, Dr. Feuchtwanger, J. W. Deems, W. E. Hidden, J. F. Kemp, Geo. F. Kunz, Wm. Niven, Ernest Schernikow, Gilman Stanton, A. Woodward, form a chain of investigators that reach to the present day, and their accumulated results represent the mineralogical history of a region now permanently assigned to an occupancy, that almost forbids much extension of their work. It is unnecessary to enumerate all the minerals of Manhattan Island in this article, and I will only introduce those to the public school teachers which are intrinsically important* and which they may, in their industrious explorations over the island, meet.

Minerals were collected on Manhattan Island first at Corlear's Hook, where a widely extended and deep deposit of drift yielded a limited range of minerals in the transported boulders brought from the north and west. The serpentine region on 10th and 11th Aves. the gneiss quarries at Kip's and Turtle Bay on the East River, from 38th to 44th Streets a region near Second Ave., between 45th and 46th St., blocks bounded by Sixth and Seventh Avenues, from 54th Street to Central Park, are instanced by Chamberlain as important localities, now, of course, obliterated by buildings. The Fourth Ave. improvement (1871-1875), and the work done in adjoining neighborhoods, brought to light a number of minerals, many, as the tourmalines, of especial beauty; at 65th Street and the Boulevard an unusual display of garnets was discovered by Mr. Gilman Stanton, while at Washington Heights and Ft. George, Mr. W. Niven has prospected successfully, adding new species to the island's lists, as well as uncovering specimens of unrivalled excellence. The Kingsbridge limestone yields white pyroxene, and nests of smoky quartz, beautifully crystallized, with a brown tourmaline tastefully relieved upon the crystalline and snowy matrix of limestone. New localities await the zealous pursuit of collectors, and while the necessary excavations are slowly reducing many geological features, the blasting involved opens up for our temporary gratification new mineralogical treasures.

Albite, the white soda feldspar, was abundant between Third and Fifth Avenues, from 93d to 101st Streets.

Apatite, the phosphate of lime, is often found in attractive green crystals, though usually broken in extraction; white crystals are also mentioned by Bailey.

Beryl, the silicate of alumina and beryllia, has, for the most part, where the specimens were really ornamental, been taken out of granite on Washington Heights.

Biotite, the magnesian iron mica, on the island invariably black has been found in crystals three inches long at 7th Ave. and 135th St., and pockets of rich crystal bunches at 56th St., between 6th and 7th Avenues.

Calcite, the carbonate of lime is found in large rhombohedral crystallizations as veins or seams in the dolomite, and recorded elsewhere as in Harlem Tunnel in thin plates, and the hornblende schist

An exhaustive catalogue of the minerals of the island up to the date of its publication was prepared by Mr. B. B. Chamberlain (Trans. N. Y. Acad. Sci., Vol. VII.) and his cabinet. together with Mr. Kunz's and the collections of the N. Y. Mineralogical Club, are on exhibition in the *Geological Hall* of the American Museum of Natural History.

or gneiss, at 122d St. and Harlem Heights, holds interesting examples in cavities.

Chalcopyrite, the sulphide of copper and iron, is found with pyrite in the dolomite beds, and infrequently in the gneiss. On oxidation it yields thin flakes or films of malachite and azurite.

Dolomite, the carbonate of lime and magnesia, the so-called dolomite of Kingsbridge, is a magnesian limestone, and is abundant at the north end of the island, holding sporadic occurrences of pyrite chalcopyrite, rutile, chlorite, tremolite, quartz and white pyroxene.

Epidote, a silicate of alumina, iron and lime, forms some of the pleasing mineral combinations on the island. It occurs in very pretty crystallizations of dark green prisms, associated with and agreeably complementary to light pink orthoclase on gneiss surfaces. A singular association of epidote and glassy orthoclase is exhibited by Mr. Kunz from Columbus Avenue.

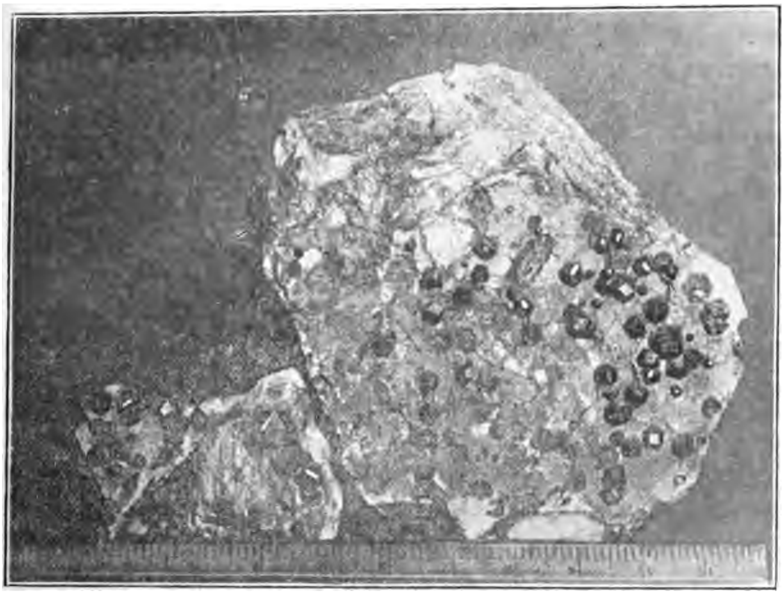

Fig. 16. Garnets from 65th St. and Boulevard, found by Mr. G. Stanton.

Garnet, a variable silicate containing, on Manhattan Island, usually alumina, iron, magnesia and lime. Garnets are plentiful throughout the island rock, dense concretions of them (the so-called seed garnet) associated with apatite, have been taken from a vein in 83d St. and Amsterdam Ave. of a pale red color, while inserted over the faces of orthoclase in a cross-cut granite vein at 65th St. garnets (Fig. 16) with modified trapezohedral faces of deep brown were found in 1888. Mr. Kunz has an enormous specimen, of a dull brown, now exhibited in the collection of the N. Y. Mineralogical Club at the Museum of Natural History, weighing nine pounds ten ounces. In many localities, especially in granite seams, this familiar mineral is encountered.

Mr. Chamberlain remarks that from Lenox Ave. and 119th St. "eastward and northward to Mount Morris Square, pockets and veins of garnets abound in greater number than in any portion of the city or county. The rocky heights of the Park are thickly studded with weathered crystals. The find of good cabinet specimens is, unfortunately, quite limited."

Mr. Niven has uncovered some large distorted crystals on the Speedway.

A group of minerals known as ***zeolites***, from their swelling and ebullition under heat, and all containing considerable percentages of water, and generally silicates of lime or baryta and alumina, are represented in the island rock in four species: ***Stilbite***, ***Harmotome***, ***Chabazite*** and ***Heulandite***. These minerals are the products of alteration and they appear upon the faces of the gneiss in crevices or exposures where a gradual transference to the surface has slowly formed them. In their most characteristic condition they are white but the island examples are brown to yellow, gray and red, and are deservedly admired.

They have been almost limited in their most handsome examples to the rocks excavated in the Fourth Ave. improvement, where the tracks of the Central, Hudson River Railroad, Harlem and Hartford Railroads were first sunk below grade.

In mentioning them Mr. Chamberlain, who himself first announced Harmotone, describes their aggregate appearance under Stilbite. He says: "Seven localities on New York Island have yielded this interesting zeolite, chief of which is Harlem Tunnel and vicinity, where the minerals associated with heulandite, harmotome and chabazite, appeared in a series of pockets and veins, running northeastward from Fourth Ave. to 102d St. near Lexington Ave. The stilbite, usually of a honey-yellow color, appeared in ***columnar***, ***scopiform*** (broom-shaped), ***sheaf-like*** and ***radiated*** masses, but rarely, as at Bergen Hill, in lamellar sections of crystals. Some of the globular groups approached a bright red in color, affording a pleasing contrast to the yellow hue of simpler forms adjacent. Among radiated forms one specimen is nearly fifteen inches square containing twenty-six rosettes. At 45th St. between 1st and 2d Aves., a second prolific locality afforded plates of stilbite two feet square.

Kyanite (or Cyanite), silicate of aluminum, is a blue to green, *flat bladed* mineral, which has been found abundantly at one or two points, and is sparingly distributed elsewhere. The place of its extreme abundance was at 101st Street and Third and Lexington Avenues. It also forms a local schist and has been so regarded.

Magnetite, the protoxide and sexquioxide of iron, is found in veins of quartz in the quartzose gneiss and familiarly in the so-called "magnetic markings" in mica, also in the granite in rather large massive black blocks.

Menaccanite, the oxide of iron and titanium, is found in flat black plates of considerable size in granite and on gneiss.

Molybdenite, the sulphide of molybdenum, a graphite looking mineral is found in excavations in flat plates or crystals, on gneiss, and quartz in veins.

Muscovite, the common white to brown mica, silicate of alumnia and potash, is a most commonly recognized mineral. The larger well crystallized granite veins yield large crystals of it, a foot across, and, under many varieties, it is widely distributed.

Orthoclase, silicate of potash and allumina, common feldspar. This feldspar is found over the island in a number of different aspects. It occurs disseminated in white grains or more compact particles in the various gneisses, it forms very pretty crystallizations over the face of the gneiss often in conjunction with epidote, while at the famous and prolific locality at Fort George handsome examples, have been extracted, and generally, in the coarse veins of granite, cleavage plates of delicate flesh-tone are obtained with sometimes lustrous reflecting beauty. It ranges in color from white to red. Graphic mixtures of orthoclase and quartz occur.

Phlogopite, magnesia mica, is distinguishable by its golden brown colors and can be usually recognized from its invariable association with limestone in which it is sprinkled. Where the dolomite becomes schistose, cleavable and merges into the gneiss rock, the phlogopite bridges over the transition.

Pyrite, sulphide of iron, the common yellow "fool's gold," is of frequent occurrence, sometimes appearing as a brilliant crust of microscopic crystals over rock surfaces, and again in nests in limestone, while irregular or minute particles appear in the gneisses and granites. Many of the pyrite specimens repay examination with a hand-glass of low power, as its characteristic crystallization is well shown, while the crystals taken from the dolomite beds are not rarely of considerable size and perfection.

Pyroxene, a mineral in composition allied to hornblende, but in the examination found on the island quite devoid of iron, where the colorless white variety prevails. It is found in the limestone in flat, brittle, striated crystals, at Inwood and the old quarries, and is exhibited in groups with quartz, from the dolomite.

Quartz, silica, is naturally omnipresent, but not frequently of cabinet interest, being usually massive. Crystals are found in the limestone groups of great beauty and smoky in color, and amethystine tints have been noted elsewhere, while many drusy incrustations are taken in pockets.

Rutile, oxide of titanium, occurs through the rocks in association with quartz and feldspar and mica, found also in the limestone. It is a dark brown or red prismatic mineral, and under the microscope is revealed in needle-like crystals in the mica.

Sphene or Titanite, the silicate of titanium and lime has been taken out by Mr. Niven in surprisingly handsome yellow plates implanted over black hornblende.

Tourmaline, silicate of alumina iron, magnesia, with boron, much varied in composition in its different forms, is one of the most conspicuous and extraordinary of the island's minerals. It is sometimes beautifully shown in stars of radiating black crystals; large splendent crystals occur in the quartz of the granite veins, the most phenomenal of which is the one figured, discovered by Mr. Niven at 171st Street and (Fig. 2) Fort Washington Avenue, while radiat-

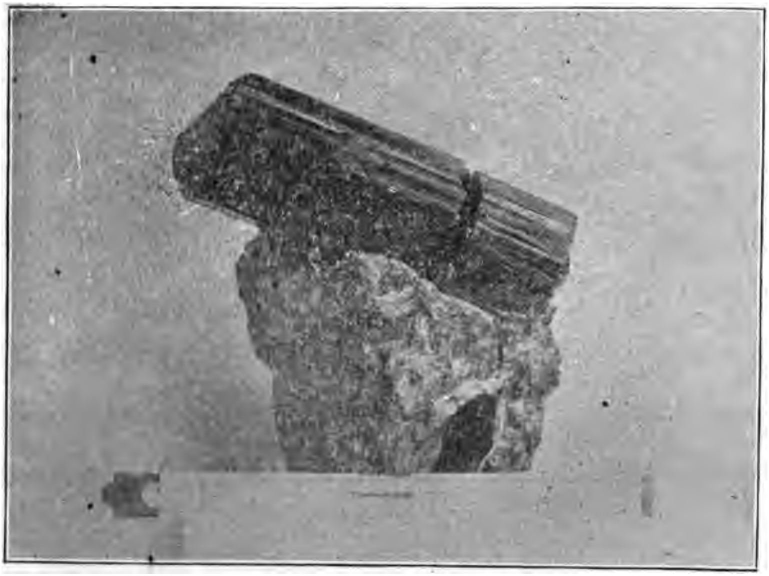

Fig. 17.—The large Tourmaline found by Mr. Wm. Niven.

groups of considerable size offer the collectors admirable and almost brilliant specimens. The tourmalines are very commonly, if of some dimensions, broken or faulted, viz: split and thrown sideways, and the intervals filled in with quartz or feldspar.

Xenotine, Monazite and Zircon, the first two phosphates of rare earths (Ceria, Yttria, Erbia Lanthana Didymyia), and the last silicate of Zirconia, have been found by Mr. Wm. Niven in the prolific locality at Washington Heights, and occurred in three pockets very near each other in a vein of coarse granite made up of granular quartz, orthoclase and "flaky muscovite." These minerals are translucent brown in colors,small but of exceedingly great interest. Another mineral which the prospecting instructor may notice, occurs in cluster of hair-like blue needles, sometimes in single blades, and is found in feldspar.

This mineral was very commonly observed, and identified as *indicolite*—as the name suggests a *blue* variety of tourmaline. Longer study and special analysis, disclosed its real composition and identity. It was the rather rare silicate of allumnia known under the name *Dumortierite.*

This mineral was at first regarded as *kyanite* and later referred to hornblende, rhaetizite, and tourmaline. It is of a beautiful blue, and in strict prismatic examples verges into greyish green. It penetrates quartz and feldspar.

The carbonate of iron (*Siderite*), formed in pea-like concretions, is found sprinkled over the gneiss, in places of a dark-brown, to yellow color, and has arisen from the decomposition of pyrite. It makes curious and attractive cabinet specimens.

Mr. S. C. H. Bailey, a pioneer explorer in the mineralogy of the island, has enthusiastically remarked of its mineral wealth that, "to one not familiar with the mineralogy of that island, it will seem scarcely credible, that a larger number of species have been found upon it than at the famous Lamoe Rock of Norway, or in the prolific mines of Arendahl; larger than the noted lists of those found at Haddam or Franklin, or any single locality in the United States."

(NOTE.—The teachers acknowledge their bewilderment before apparently deceptive variations of a mineral species. They confess to a sense of despondency and despair, when having fixed an association of color and structure with the name of a mineral, and they find variety and instability. This discouragement is natural but it will be short-lived if the teachers continue their studies. Gradually from amid the impressions of a mineral a series of typical images will emerge, which will mark its ordinary and typical form, and around these the varieties will group themselves with the relative hardness, the usual color, and if possible the crystalline form, and despite changes in color or texture they will find a mineral preserves a reasonable identity under all variations.

The varieties will eventually add a new charm to the subject, and they will become a new element of interest. By constantly collecting and observing and resorting for assistance to some expert for aid, they will find the subject become more and more clear, fixed and definite).

THE BOROUGHS OF BROOKLYN AND QUEENS.

In the Boroughs of Brooklyn and Queens we find a generalized expression of ice agencies in the drift. The whole region expresses the tumultuous transportation from the north of material furnished by the multiplied agencies of frost, denudation, weathering and mechanical stress. Clays, sand, gravel, and great hills of conglomerate, packed from top to bottom with cobble-stones, tell the singular story which the long, tireless and infinite retinue of *glacialists* have been engaged in translating these long years. The subject is a fascinating one and the innumerable diversity of features which adds to its interest, challenges an imagination to reconstruct conditions remote and unusual.

The physical features of Brooklyn and Queens are the most simple aspects of the subject. The whole region is a section of the Terminal Moraine—that chain of hills, hillocks, mounds and detrital ridges which, in a broken and angulated succession, stretches from Cape Cod or, indeed, the Fishing Banks on the east to the State of Washington on the west, if the researches and conclusions of our geologists are credible.

The rock basement, identical with the schists of Manhattan, upon which the Drift rests, appears in Astoria, Long Island City, and under Blackwell's Island. The latter was thoroughly established upon the completion of the East River Tunnel of the East River Gas Company, which, beginning in New York from the bottom of a shaft, 135 feet deep, penetrated rock through its entire course, except in the east and west channels of the East River on either side of Blackwell's Island and emerged in rock under Long Island City, through a shaft 147 feet deep. The entire superstructure of the land over these basal beds is not entirely drift. Conclusions are rapidly approaching proof that a widely extended group of clay beds referable to the Cretaceous, and possibly Tertiary formations, underlie Brooklyn and Queens or, indeed, all Long Island, and on these rise the great morainal piles which are yet well characterized in undisturbed perfection within the limits of Brooklyn City. They are reviewed in the accompanying paper.

Dr. Merrill's description of the rocks of this section can be instructively quoted: "The Fordham gneiss forms the high anticlinal ridge which borders the New York shore of the Hudson river from Yonkers southward to Spuyten Duyvil, and also that on the west side of the Bronx valley. The former ridge terminates on the south at Spuyten Duyvil and does not reappear on Manhattan Island. The latter is bifurcated at the southern end, and the western fork interrupted by a cross-fold at the Harlem River, ends on

Manhattan Island in the low ridge which borders Seventh Avenue on the west at 155th Street, and disappears by pitching below the general surface level about half a mile southward. The eastern fork which, owing to the same cross-fold, disappears beneath the limestone in Morrisania, reappears near the Bronx hills in Mott Haven where it forms a low anticlinal ridge, interrupted by the Kills, and represented on Manhattan Island by a few outcrops below highwater mark at the foot of East 123d and 125th Streets, which are now obliterated. Some narrow anticlinal ridges of Fordham gneiss are seen as the islands in the East River, notably Blackwell's, Ward's, North Brother's and South Brother's, and it is the only stratified crystalline rock at present exposed on Long Island, in L. I. City, Ravenswood and Lawrence's Point."

THE BOROUGH OF THE BRONX.

The Borough of the Bronx embraces a region that stretches eastward to the Sound and encloses the low winding valley of the Bronx—a picturesque but shrunken stream which only in spring exhibits the congruous features of a river. This borough otherwise continues the geological features of Manhattan and in the main is a a group of north and south ridges with a strike approximating that of New York (N. 40° E. magnetic) declining eastward to the waters of the Sound from the high bluffs of Fordham and Van Cortlandt Park, and separated by valleys, or lower areas, with a drainage to the southeast.

It has not been so much opened as the region of Manhattan Island, though in its general aspects of gneiss rock and granite veins, surmounted here and there, as formerly, at Mott Haven, by prominences of limestone, it displays the features familiar to all observers on Manhattan itself, and promising the same mineral disclosures when more thoroughly explored. The glaciation is marked and significant and, in this respect, it forms only a pendent to the identical features of Manhattan Island.

The gneiss ridges seen on the north side of Westchester Avenue, the gneiss rock of Fordham Heights, the gneiss in the Bronx gorge all present and duplicate the familiar features of Manhattan Island; but the gneiss typically shown at Fordham has received an interpretation somewhat at variance with the assumption of their complete identity.

Prof. F. J. H. Merrill has called attention to the rock character of the Highlands far north of Manhattan Island as being composed of fragmental rocks, chiefly feldspar and quartz, and mainly designated under the term *granulite*. He has traced a series of beds of rock laid over these southward, and has urged that the red gneiss, which he considers typhically shown at Yonkers, and therefore called by him *Yonkers gneiss*, underlies the gray gneiss of Fordham or *Fordham gneiss*, and that this again underlies the micaceous gneiss or schists of Manhattan Island, which latter he terms the *Manhattan gneiss*. This view has considerable interest and will enlist the attention of the teachers to the fact of the varying character of these three groups of rocks, no matter whether the inference drawn from them by Prof. Merrill is correct or not. They will observe the more ferruginous stained reddish gneiss, on and near Jerome Avenue, a little north of the New York City line, made up of small grains of quartz, fragments of reddish orthoclase and biotite, viz. the Yonkers gneiss. Then they may notice the Fordham gneiss (200 feet thick) which is gray, made up of biotite and quartz, with layers of pure biotite schist and white quartz rocks, to be met at Fordham Heights, and on Seventh Avenue and Northern Boulevard. And then the mica schist or very micaceous gneisses of New York Island.

A feature of further interest in the Borough of the Bronx are the limestone beds—beds in all respects similar to those studied at Kingsbridge. They lie in the river valleys, or more correctly, the rivers have formed their valleys in the limestone depressions as more easily eroded and dissolved. Tibbit's brook has worn its channels partially in a limestone rock, the northern extension of the Kingsbridge dolomite, the Bronx River has its head in limestone at and north of William's Bridge, and it may be so with Westchester and West Farms Creeks.

BOROUGH OF RICHMOND—(STATEN ISLAND).

Staten Island is a triangular territory embraced by the waters of the Arthur Kill on the west, the channel of the Kill von Kull, New York harbor on the north and the ocean and Raritan Bay on the east and south. It contains about seventy-seven square miles; is ten and a half miles long in its extreme axis, and at its widest part attains a width of seven and three-quarter miles.

It consists essentially of a north-east and south-west range of low serpentine hills (from 300 to 380 feet in elevation) resting upon or within crystalline schists, similar in all probability, with those we have reviewed so conspicuously shown on Manhattan Island. An evidence of these was formerly visible before the old Nautilus Hall at Tompkinsville. Here was exposed a broad vein of granite, eighty feet wide and fifty feet long.

Upon the serpentine hills as a centre is superimposed, like a marginal expansion, a skirt of later formations, which widen the narrow island of primary hills and also prolong it into a southern terminal angle at Tottenville. The nucleal geological feature, therefore, of the Borough of Richmond is the serpentine hills. They form a broad belt covering, perhaps, a superficial extent of fourteen square miles, their eastern limit rather sharply defined by an abrupt terrace, from the foot of which stretches a coastal plain to the sea and Raritan Bay, their western flanks more gently sloping beneath a mantle of drift. They are broken through at a lower level by several natural passes or cloves, and a number of exposures afford the student and collector desirable opportunities for comparing their mineral features.

In a northeast and southwest direction they rise permanently in rounded domes from the edge of the channel of the Kill von Kull and New York harbor and, with a fairly uniform range of elevation extend to Richmond at the centre of the island, where they sink rather suddenly beneath the inundated expanse of the Freshkill meadows.

The serpentine assumes, at but a few points, a characteristic yellowish green, being usually pale in color and even whitish from weathering, though tints are found quite deep and attractive. It is also almost black, and in texture compact to earthy. Talc and unctuous surfaces are found associated with the serpentine, and apparently its derivatives. Collectors will find serviceable material at Pavilion Hill, a very short way back from the water side at Tompkinsville.

The only other massive rock at Staten Island is the so-called "trap," an igneous rock forced upward from some deep-seated source of fused or molten mineral matter. This trap dike, exposed in quarries at Elm Park, a short distance from the shores of Kill von Kull, and at Graniteville (Fig. 18), represents the *Triassic* rocks, the first stage of Mesozoic time. There are no Paleozoic rocks on Staten Island and the great gap from the crystalline schists to the Mesozoic is left vacant. The new sandstone (Trias) first succeeds the serpentine terrain and, though shales and sandstones compose the Triassic strata. these are only sparingly shown in the Borough of Richmond in a few meagre exposures, as at Shooter's Island and the opposite shores. The protruding dike of "trap" is its most evident witness.

The trap rock (diabase) is famillar to teachers as the "New Jersey Bluestone," formerly used in Belgian pavement, and probably more closely associated in their minds with "boulder drift," of which it forms in the area of the Greater New York so large and evident a member. "Trap," or probably Diabase is a mixture of a plagioclase feldspar, usually labradorite and pyroxene, (augite) with frequent veins of hornblende, seldom some amorphous quartz, a sprinkling of pyrite and magnetite, an occasional mica flake, with products of alteration, as calcite, chlorite, and serpentine. It varies in its texture from a dense iron-gray flinty ringing rock to a more open crystallized "pepper and salt" appearance, weathering into rusty crusts, or crumbling away in sand. It has been improperly termed granite, to which in no sense, either in composition or origin can it be referred.

Industrially it has been in great demand and now used for road metal its usefulness exceeds all previous adaptations. The Palisades are its most familiar exponent, and the low burrowing trap ridge, scarcely emergent above the surface of Staten Island is the declining and subterranean extension of that escarpment.

Fig. 18.—Trap Rock at Elm Park, Staten Island.

The trap dike on Staten Island has an interest exceeding its mere lithological features. It indicates the presence at great depths, perhaps, of that group of rocks—the crystalline schists and gneisses—which seem so representative of the underlying geological structure of the Greater New York. And in this way, Prof. Nason in the reports of the New Jersey Geological Survey urged that the trap dikes of that State had been forced outward through crevices originally existing in the deeply-laid archæan rocks, viz: in rocks similar to, if not identical with the crystalline schists. Without pausing to review the evidence he presents, and admitting his hypothesis, the trap dike on Staten Island indicates a probably similar position of origin, and so enables us to assume that this primary rock at considerable depths forms the basement flooring of the western sections of the borough. So in relation to the assumed fundamental platform of rocks upon which all the later formations of Staten Island rest, of which platform the granite vein at Tompkinsville was a suggestion, a platform likewise continuous with the schists of Manhattan Island, and like them archaean in age, there is some significance to be given to this *trap* dike.

This dike can be traced from Elm Park (north shore) back into the island for over five miles, forming a low swell, and either bending or bifurcating toward Long Neck, disappearing beyond Linoleumville in the waters of Arthur's Kill.

Fig. 19.—Clay beds near Kreischerville, Staten Island.

The Cretaceous Formation appears next above the Triassic, and doubtless forms a large part of the borough extending southward and eastward. It is represented by beds of sand and clay, the latter black, white, yellow and brown, which outcrop, or have been uncovered in considerable force at and near Kreischerville. (Fig. 19.) Lignite and vegetable remains appear in these beds, but a really satisfactory source of fossil plants has been discovered in the concretions of clay cemented by limonite (hydrous iron oxide). These oval, flat, or circular nodules have been dislodged at various points along the southern and eastern borders of the island, and their contents both of plants and shells, have proven, by their cretaceous affinities, the probable age of some bed or beds from which they were derived. Mr. Arthur Hollick has industriously investigated these "finds," and the evidence, now accumulating for many years, approaches almost demonstration of the widely extended area of these cretaceous deposits. They are a part, along the coastal shelf, of the same formation in New Jersey, and are continued eastward through Long Island; a series of beds dipping to the southeast and representing the final assortment of the products of decomposition of granitic rocks, whereby the clays and siliceous sands have been separated in comparative purity in distinct but variously alternating beds.

These cretaceous layers have been largely buried up beneath drift material, or possibly in places disarranged and crowded into confused and misleading positions by the glacial push. They have been penetrated by iron waters which have cemented their sands and gravels into coarse conglomerates.

The Ice Age was the next period which registered its presence in the surface rocks of the Borough of Richmond and left over the greater part of it the commingled mass of stones, earth, boulders, sands, gravel and clay. It is treated in the accompanying paper. The strictly modern period succeeded, and those present features of the island were then added which surrounded it with deep beds of sand, built up extensive marsh lands, cut down its hills and sculptured its drift into ravines and valleys.

A pleasant mineralogical excursion in the Borough of Richmond can be made from the landing place at St. George, by taking the trolley cars running on the Richmond turnpike to the Clove, turning at this latter point to the left and walking south to the Little Clove, whence an ascent upon a winding road, leaving the former (the Little Clove) upon the left, brings the pedestrian to a portion of Ocean Terrace. Excavation pits and mounds overgrown with grass or herbs advertise the location of a surface mine. This is one of the limonite ore beds of the island. This ore has been concentrated in favorable positions, probably depressions, and has been derived partially from the serpentine rocks, just as along the eastern seaboard similar ore bodies have been formed from the disseminated iron in the limestones. It seems also that contributions of iron oxide have been made by surface waters leaching it from the drift. Specimens of some beauty both of limonite and crystallized quartz were found formerly in these excavations. In the locality described the position might seem anomalous at the summit of a hill, but it must be recalled that the actual topography of the past at the same point was different. Besides changes of level which may have taken place the original serpentine hills were much higher and this summit, to-day, was once a zone of concentration below surrounding slopes, while water springs laden with iron coming from below contributed their portion of iron oxide to the deposit. In 1887 the writer called attention to the probable origin of the serpentine hills of Staten Island in altered hornblende and, since in the decomposition of hornblende the iron oxide becomes more and more concentrated, rising in some examples from eight to eighteen per cent. (Merrill), the process of change which resulted in serpentine, assisted the creation of limonitic deposits. The wonder really is that they are not deeper and more general.

The ore beds in the Borough of Richmond have yielded something like 300,000 tons, partly for blast furnaces and partly to produce red ochre paint. The clays of the island have furnished refractory ware and brick. The trap rock has been used in local construction, house and bridge building, and widely for pavements and road metal. The serpentine in beds becomes fibrous and has been mined for "asbestos," though such a use of it is very limited. The very heavy and inexhaustible beach sands prevalent at Seguin's Point, Ward's Point and Prince's Bay have been shipped to New York and Brooklyn. The black oxide of iron (magnetite) occurs in considerable quantities through the beach sands on the southern shores, but it has never been of any economic value.

The rocks which will naturally control the attention of the teachers will be the serpentine, whose configuration in a broad band of undulating summits is so pleasingly seen from the lower bay. The serpentine is a silicate of magnesia with water, and it is a mineral or, when occurring in extended beds, a rock, over which a great deal of discussion and speculation has arisen as to its origin. It is generally supposed not to be an original deposit but a result of changes in earlier rocks or minerals by which a sort of residue, this hydrous silicate of magnesia or serpentine remains, the other chemical elements of the primary mineral being removed by solution, or in some other form deposited within or along side of the serpentine itself. It will be recalled that in the paragraph on the serpentine of Manhattan Island, the original mineral was found to be an amphibole (hornblende or actinolite) whose change had produced the serpentine and secondary calcite.

The great serpentine beds of Staten Island seem to have originated in a similar way from identical conditions. If they have, this would also justify an auxiliary inference that these basal rocks of the Borough of Richmond are also the equivalents of and contemporaneous with those of Manhattan. The theories regarding the origin of the serpentine may be gathered under four heads. First, those that assign it to altered eruptive and volcanic rocks or metamorphic schists; second, those that trace it to replaced sedimentary beds of limestone or dolomite; third, the abandoned hypothesis of

Dr. Hunt that it was a *chemical precipitate* resulting from the interaction of soluble silicates and chloride and sulphate of magnesia; fourth, the obsolete notion that it was an extended mud forced outward through the earth's crust.

But an examination of a number of microscopic thin sections of the island serpentine taken from distant points proves that it at least has on Manhattan Island originated in an altered hornblende. The sections showed the characteristic curdled, shreddy and broken appearance of serpentine and reveal, between crossed Nicol's prisms, luminous colored spots and crystalline fragments of hornblende. There seems left little room for doubt as to the origin of the serpentine in question as coming from hornblende masses, and we may regard the greater part, if not all of it, as a derivative product, resulting from altered crystalline metamorphic rocks, generally referable to the amphibole groups.

We thus add another consideration to the establishment of a community of origin for the *underlying* rocks of all sections of the Greater New York; the crystalline schists representing a nexus of geological vicissitudes, synchronous and identical.

THE EVIDENCES OF GLACIATION IN AND ABOUT GREATER NEW YORK.*

THE ICE AGE.

At the end of that long course of geological time, from the Archæan to the Tertiary, which built up the solid portions of the earth in their present configuration, geologists recognize, in the evidence before them, the proof of a remarkable period—a period so startling that it might justly be accepted with hesitation, were not the conception unavoidable before a series of facts as extraordinary as itself and which, partaking of its astonishing character, are explained upon no simpler hypothesis. This era is known as the glacial. It has left its monuments over the surface of either hemisphere and written its history upon their rocks.

It was an epoch of arctic rigidity. The cold regions of the pole extended their contracted circles over the temperate latitudes and enveloped in a mantle of ice lands which had been the home of an abundant and tropical vegetation. The skirts of the glacial sea which spreads its icy surface over polar lands became so expanded as to hide the surface of the earth within its frigid folds down

* *I have been permitted* in the opening pages of this article to appropriate language used *in a paper by myself in the* Popular Science Monthly in 1878.

to the latitude of 39° north. The evidence which has established the presence of these arctic conditions is complete and irrefragable, and, though there is to-day a recession from the former extreme positions of glacialists there can be no wholesale denial of the facts. In America especially the proofs are more convincing than anywhere else in the world.

It was Agassiz who first insisted, perhaps almost with trepidation, that Central Europe, England, Scotland and Ireland had been buried beneath solid ice; that from the mountain-tops of Scandinavia, the Grampians of Scotland, the Lake Hills of England, and the summits of the Alps had proceeded rivers of ice, whose confluent seas swept over Europe and grooved it with valleys, channeled the courses of its rivers, engraved its rocks, scooped out its lakes, and scattered their burden of debris far and wide over its plains. The conception was a bold, almost a terrifying one, and because the actual history and nature of glaciers was so little known it was regarded with aversion and spoken of with contempt. Agassiz had laboriously studied the glaciers of the Alps, and he knew so well their character and their physiographic significance that he recognized elsewhere the evidence of their past presence.

Venetz, Rendu, and Charpentier, had preceded him in glacial study and had insisted upon an extension of the Alpine glaciers far beyond their present beds in past ages, but had not realized the immense utility of these views in explaining the glaciated surfaces of Europe. Forbes, Hopkins and Tyndall succeeded him in the investigation of glacial physics, and by their close scrutiny into the constitution of ice and the laws of ice making and glacial motion, fairly established a new department of physical science and added confirmation to the views of Agassiz.

Let us examine some of these singular and hitherto inexplicable records which elicited Agassiz theory and which, long before they were harmonized by that assumption, had been attentively examined by geologists and explained upon other grounds.

The rocks as they lie in place, the flanks and summits of mountains to heights of 5,000 and 10,000 feet, and the surfaces of outcropping masses over immense areas of the world, are gouged with channels sometimes a foot deep, sometimes eight feet deep, with widths from two to three feet. These groovs, of all dimensions, pass over the rocks in groups, like mouldings, and the rocks they occur upon are polished and oftentimes lustrous. The channels diminish in size to the faintest striae which, like sharp scratches cover the surface, running along at times in parallel series, or diverging in different directions, as though the great primitive plane had varied its course over them, scouring with exquisite fineness.

In the same region they have the same direction. They seem, as it were, with us, to stream from the north, and wherever other scores contravene this, these secondary markings are themselves harmonious, indicating some subsequent action upon the rocks, in character similar to the first, though varying in its motion and probably restricted in its extent and importance.

Thus the scores upon the rocks of New England point north-west and south-east, and only local derangements disturb this prevailing direction. The easting increases as we progress to the ocean, reaching its maximum in Maine and the borders of Canada; while, as we retire from the margin of the states, we observe that the scratches and grooves acquire a north-and-south direction, becoming nearly meridional over New York, and there slowly swing round to the west, until in Ohio, Indiana, Illinois, Wisconsin and the western limits of the continent they lie pointing north-east and south-west. In the east they assume a rudely outlined radiation from the highlands of Canada, and stretch out from an hypothetical centre like the multiplied spokes of a great wheel.

In Switzerland they sweep down and out from the central ranges of the Alps in all directions, and, while locally uniform, they converge from the south, and east, and north, and west, toward the lofty slopes and pinacles of this assemblage of mountains. Over West Russia and Northern Europe, where the markings are discovered, they indicate the Scandinavian mountains to have been the seat of whatever disturbance or agency has fluted and engraved the continent. Similarly as the rocks lie related to the Highlands of Scotland, the Lake Hills of England, or the mountains of Wales, the striae impressed upon them extend toward every point of the compass. They stream north and south from the summits of the Pyrenees, from the peaks of the Caucasus, and down the valleys of the Himalayas. It must be remembered, however, that these conclusions are based upon an average of the bearings of the groove in each instance, and that these are infinitely varied by the construction and irregularity of the land.

Thus, over great portions of the world, we find the rocks furrowed, polished and striated, in long, frequently deep and rectilinear grooves, which lie in groups and series identical in direction and pointing to associated highlands, or distant continental mountain ranges, as the source of whatever strange and inexorable instrumentalities have produced.

In the White Mountains, the sides of the mountains, the valleys, the top of Mount Washington at 5,000 feet above the sea, are all cut with these strange furrows, the rocks polished, and the whole country bearing these evidences of past erosion wherever the naked rock meets the eye. Over Maine the same phenomena present themselves in endless succession; the grooves crossing the country and losing themselves in the sea along the coast, while they corrugate the borders of innumerable bays and the walls of the deep fords that indent the shores.

These furrows can be traced for miles across the country, cutting the three ranges that lie between Bangor and the sea almost at right angles, traversing these highlands as though they were level surfaces, dipping beneath the sea and reappearing upon the sides of Mount Desert to be again lost in the waters of the Atlantic. Unquestionably, over that sea floor, could we follow their course, the same furrows continue to the verge of the continent which lies miles out to sea, where the steep edge of the land falls precipitately to the true bottom of the ocean. Over the west, throughout Canada, and upon the ancient rocks of the Great Lakes, these evidences of past erosion exist upon an enormous scale. As a rule these striae indicate a planing surface advancing from the north and, though a second series may occur, as upon the islands of Lake Erie from east to west, whose furrows obliterate the first inscription, such marks are local merely and infrequent. Again, upon the Sierras, the tops and declivities of the ranges are scored and engraved with the indelible signatures of past erosions, and the rocks of the barren wastes of British America are signalized in the same manner. The Sierra scorings are largely local. So much for striae; we perceive their universal presence and their marked reference to the north, or to elevated regions which dominate our level plains.

The second feature of this epoch, designated by common consent, the Drift, is a series of surprising facts, showing, through all this deeply-scored and paneled country, the past presence of extraordinary transporting agencies. We find rocks of enormous size, in some instances weighing 3,000 tons, planted in fields and lowlands, or strown over hills and moors, where no rock lies in place, sunken in the soil where the lithology of the soil is entirely distinct, while that of the monoliths themselves is identical with rocks many miles northward. Gigantic boulders—Titanic mementoes of the past—are scattered over Central Europe, over Germany, Holland and Russia. They are identical in character and can have no nearer origin than in the mountains of Scandinavia.

Some of these blocks of stone are of incredible dimensions, and are accompanied by innumerable smaller ones that lie over these districts as if flung in sport by some preadamite Antaeus. They have served the most useful purposes in the flat countries through which they are found, being used for buildings of every description, and their smallest associates have helped to pave the highways between Hamburg, Magdeberg and Breslau. Accredited in ruder times to the malevolent agency of man's spiritual foes, they were called ***devil-stones***; but science, recognizing their distant origin, has named them ***erratics***, and the Germans, more picture-esquely, ***wanderers***. Not only are they found upon level and loamy lands, utterly unaccountable, except by the assumption of transportation, but they are also discovered capping the cliffs of mountain chains, hanging by the side of depths over which they must have been carried and into which, by the Nemesis of destiny, they are now doomed to fall.

The Jura mountains, north of the great valley of Switzerland, and opposite the western or Bermuda Alps, along the frontier of France, are thus studded with these boulders, some of them containing 50,000 to 60,000 cubic feet of stone. These have come from the Alps; they are crystalline rocks, gneiss and granite, and they lie upon ridges of limestone. They are virtually nothing less than dislocated fragments of those abraded and decreasing hills, perched upon the Jura cliffs. Prof. Guyot has placed beyond all doubt, their home upon the summit and sides of the Swiss Alps, and shown that they have attained their present eminence by a positive carriage from these original localities. This position has, indeed, been made impregnable by a protracted and laborious survey of innumerable "wanderers," found upon the Jura, whose lithological character identified them with the Alpine formation, while it served to trace the probable path of their transmission. These blocks have been found at elevations ranging from 2,000 to 3,000 feet above the sea, and in Carinthia similar erratics have been described at great elevations, proceeding from an opposite quarter of the Alps.

In North America, and especially throughout the Northern States, the boulders are numerous, often of great size, and indicating transits of many miles. Over the Eastern, Middle and North-western States, boulders, that have emigrated from distant points to the northward, occur in such abundance that they may almost anywhere be found if the inquirer will only examine the country he passes over. Upon Mount Katahdin, in the Moosehead region of Maine, stones can be seen, lying over 4,000 feet above the sea, fossiliferous in their nature and coming from northern sites; while toward Mount Desert, masses, some forty to fifty feet in height, are sprinkled everywhere, and, as in the case of the Dedham granite distributed to the south, invariably show northern origin. In Berkshire County, Massachusetts, these traveled rocks lie in long alignments, passing over the Lenox Hills, and extending in a generally south-easterly direction for fifteen or twenty miles, and have been filched from the Canaan and Richmond Hills across the line in New York, being of chloritic slate, with angular specimens of limestone intermixed.

Some granites from Vermont, on the west of the Green Mountains, have been lifted over these barriers and transferred to the southern margins of Massachusetts; while in Vermont a boulder weighing over 3,400 tons, and known as the Green Mountain Giant, has been drifted from the Green Mountains easterly across the valley of the Deerfield River, and planted 500 feet above that stream. In Michigan, near the Menomonee River, a field upon the northern slope of a mountain is densely covered with boulders, so that a mile can be traversed without once touching the ground. Again huge nuggets of copper, torn from the immense deposits of native copper at Keweenaw Point, Portage Lake, and the Ontonagon district, on the southern shore of Lake Superior, are found widely disseminated to the south of these localities in Michigan, Wisconsin, Ohio and Minnesota, a few of which have weighed 300, 800, and one 3,000 pounds. From the sides of the White Mountains fragments of rock have been carried away, and not only conveyed southward but as Agassiz first pointed out, distributed northward, though only at comparatively slight distances.

Throughout Ohio, boulders are found which are composed of rock utterly foreign to their present surroundings; indeed of material not known within the limits of the State. These are found perched over declivities, buried in the soil with their exposed edges showing above the surface, or else lying unencumbered in slight depressions of the ground. In Indiana, Michigan, Illinois, Wisconsin, etc., they are omnipresent, and the streets of Cincinnati are paved with the smaller specimens that crowd in exhaustless trains upon the footsteps of their larger companions.

In short, we gather the irrefragable testimony, wherever we look for it, through our Northern States, through Europe and Asia, and even along the western coast of South America, that some immense force has been exerted in time past, not only to dislocate and shatter the rocky barriers which opposed it, but also to carry them in its southward movement far removed from their place of origin. Further, let it be remarked that, though one class of these erratics is composed of angular and unworn stones, another yields boulders that have undergone severe attrition, and along their larger axes are striated and polished; bearing in mind, moreover, that the direction of their transit coincides with that of the furrows and flutings in the same region, we may strictly conclude that they are a feature also of the same excessive and gigantic system of erosion.

But there is a group of deposits of a yet broader and more significant character in its general relations than the foregoing. Over Scotland, England, Ireland, Scandinavia, Denmark, Central

Europe, Switzerland, Prussia, France, Spain, and in North and South America, in short, wherever we discover boulders and grooved surfaces, we find a deep and characteristic deposit, not the work of alluvial formations or recent detritus, for it underlies these, but the record of a vast disintegration which has covered the land with sheets of gravel, clay and sand, all intermixed with stones and boulders, variously combined in their order of succession, and ranging in depth to over 300 feet. These immense beds furnish gravel for roads and ballast, sand for glass making and mortars, and clay for brick; their included stones and fragments are scored and embroidered with fine and interlacing striae, and they cover the furrowed surfaces of either hemisphere for miles. They represent the accumulated wear and tear of continents, under some extraordinary agent of erosion and denudation, whose teeth have resistlessly ground upon the solid rocks of the hills and highlands, hiding disfigured surfaces beneath a covering of ruin.

Over New England the same deposit is widespread; it lies up and down the valleys, it forms the terraces of its rivers, the shores of its lakes, and, spread over the face of the land, is frequently the immediate soil beneath the feet. This member of the geological series, exhibiting various phases in its deposition, from the boulder clay to the lake ridges, is widely distributed, indeed is widely universal over the Northern States, and as far south as 40° north latitude extends its sheets and centres of pebbly and sandy deposits in mounds and ridges themselves capped with accidental boulders, and resting upon the furrowed and seamed surfaces of the rock beneath. Sometimes they may be found collected in heaps and walls at the foot of the polished rocks, as if silent and incontrovertible witnesses of their severe and prolonged erosion.

In Scotland it is the *till*, a stiff clay, interspersed with polished stones, crowding down the valleys and prevalent over the lower slopes, varying in its lithological character with the character of the surrounding rocks. Gravel and sand beds are intercalated with it and superimposed upon it. In England, Ireland, Scandinavia and Switzerland, we discover identical strata-strata which, while yielding different subdivisions, in their entire extent are the same thing and only varied according to the local force and extent of the wearing agent, the local peculiarities of the country over which it operated, and the effect which submergence beneath the sea had in redistributing and rearranging the beds of detritus, already laid down. Associated with this phenomena are the appearances known as crushed ledges and *roches moutonnées*, both of which testify to the exertion of enormous pressure—the one of pressure continuous and progressive, the other, perhaps, of percussive and intermittent attacks.

CRUSHED LEDGES designate those plicated, overthrown exposures where parallel laminae of rocks, as talcose schist, usually vertical, are bent and fractured, as if by a maul-like force battering on them from above. The strata are oftentimes tumbled over upon a cliff side like a row of books, and rest upon heaps of fragments broken away by the strain upon the bottom layers, or crushed off from their exposed surfaces.

Roches moutonnées are those rounded and swelling prominences often seen in a landscape which, when examined more closely, show themselves to be truncated masses of rock whose asperities have been smoothed away by the same agency which has planed the rocks everywhere. Only the *roches moutonnées* have been left furrowed and scratched upon one side, whence the abrading and engraving tool advanced, but upon the other unscored and hidden beneath a tail of fragments ground from their opposite slopes.

Thus, imperfectly described, we have reviewed the most prominent features of a comparatively modern period, viz: the widely grooved and polished condition of northern rocks; especially hard-grained rocks, which retain these impressions; the occurrence of wandering boulders, transported larger or shorter distances from their primitive sites and the detrital matter, from continental abrasion, deeply burying the rocky face of the country and in ridges, mounds and sheets extending east and west and along the great water-courses, stretching itself down southward in irregular tails, curves and projections.

Prepared now to detect the traces and monuments of this stupendous geological agency, let us briefly look for the evidence that establishes its past presence in and about New York.

II.

PERHAPS no more convincing testimony to the reality of some remarkable transporting action could be found, than that offered by the drift boulders. They are so large, so far removed from their original homes, that only the most invincible prepossession would fail to see in them the proof of a mechanical power wholly incommensurate with ordinary geological agents, as floods, shore ice, or gravity.

The levelling of the drift hills of New York has very greatly reduced the number of large boulders now to be found on Manhattan Island, and some of the longer and more remarkable are to be found outside of the city precincts. But we have records of some of these transported giants with such dimensions as to clearly show their size with some reference to their character and origin. Dr. L. D. Gale, who has made the first systematic examination of the local geology has put on record the following notes:

At Tenth Avenue and 24th Street, a boulder of "asbestos rock" four to five feet in diameter, with boulders of greenstone, (trap,) granite and sandstone. The "Asbestos rock" is hydrous anthopyllite occurring at 59th Street and Eleventh Avenue, though it must have extended father north.

At 25th Street a boulder of sandstone, nine feet long and seven feet high, was recorded.

At 64th to 66th Streets boulders of sandstone, greenstone (trap) and anthophyllite.

At 77th Street boulders of greenstone, while along the shore in all directions trap from the diabase dike of the Palisades, and sandstone from the Triassic Sandstone of New Jersey.

At Eighth Avenue in the neighborhood of the Lunatic Asylum, then north of Bloomingdale village, Dr. Gale records this striking observation; "an immense boulder of granite resting on the rock near the southwest corner of Mr. Steven's house, and nearly round, having a diameter of ten and eleven feet. There is one very large groove between this boulder and the northwest whence it came. It seems to have been cut by this very rock, inasmuch as it terminates with the boulder on the southeast, and is covered by the soil in less than a rod from the boulder. This groove is three inches deep and eighteen inches wide.

On Fourth Avenue near 14th Street, he observed boulders of immense size, some of which were ten to eighteen feet in diameter.

On Third Avenue to the East River about 50th Street, trap, granite, sandstone and limestone (much less frequent) boulders were recorded by Dr. Gale, all northern imigrants.

It would be wearisome to rehearse all of Gale's observations; they repeat each other continuously, boulders, boulders, boulders, of trap and sandstone brought from the northwest in New Jersey, with no inconsiderable number torn from higher hills on the north, on Manhattan Island itself, notably the persistent anthophyllite (actinolite) rock.

At present there are but few boulders known to the writer within the limits of the Borough of the Bronx, that is the large monolithic type called "erratics" or "wanderers." In the Borough of the Bronx, the "rocking stone" at Bronx Park (Fig. 20), is interesting, being a large fragment of very coarse granite about ten feet long, perhaps eight feet wide and eight and one-half high. It resembles in texture the coarse granites of Westchester County, and probably has not traveled a great distance from its home to its present location. The surface on which it stands is glaciated and smoothed, and indicates to the eye its planed and dressed condition.

In Central Park a number of boulders of very coarse somewhat pegmatitic granite can be readily found. They are beautiful themselves in their colors and structure, the pink orthoclase, greenish plates of mica, and projecting nodules of milky quartz forming an attractive mineral combination. But their interest is quickly enhanced when they are recognized as "travelers," whose vehicle of transit has been moving ice. They are located on the borders of the "Sheep Pasture," one near the "Mineral Springs" (sic), and a group at the south side of the same expanse, upon and near surfaces of gneiss scratched and furrowed, most unmistakably. These boulders vary somewhat in size, and average 8x3x5 feet in cubic dimentions, or represent, each in weight nearly ten tons. (Fig. 21).

The boulders in Brooklyn, both numerous and large, were distributed over outlying fields, protruding in shoulders out of the ground, or buried deeply in the morainal mass. Mr. J. A. Grenzig,

Fig. 20.—Rocking Stone, Bronx Park, showing glaciated gneiss surface.

who has recently paid considerable attention to the mineral contents of the drift in Brooklyn, remarks upon the rapid disappearance of the boulders by blasting and breaking, since they furnished useful building material. He says "the places which formerly had many large boulders on the surface were mostly on the west or northwest of the ridge of highland running from Prospect Park northeast, along what is now the Boulevard to East New York, and then on to Jamaica, also on the ocean side of this highland where it disappears in the plains." West of Prospect Park, the highland follows a more southerly course toward Fort Hamilton, and, as Mr. Grenzig indicates, the large boulders west again of this ridge were numerous.

A very picturesque and almost startling example of a boulder can be seen to-day on the shore road running from New Rochelle to Bartow, (Fig. 22). It is a huge granite mass perched attractively on a low knoll, forming a natural foil to a neighboring villa.

The boulders on Staten Island are innumerable, though their former conspicuous display has sensibly contracted. The building of stone walls and especially the construction of the Rapid Transit Railroad along the north shore of the island has both buried them out of sight and turned them to use as well. Formerly the shores of the Kill von Kull on its south side quite contrasting with the far

Fig. 21.—Drift boulder of granite, Central Park.

less encumbered north shore of the same channel was thickly strewn with boulders of all sizes. Above them rose a terrace as at present, and from its summit backward over the island with the centre of their distribution rather nearer the shore, these boulders appeared over field and hillside. They were plainly foreign. Unless dropped from the skies they never could have reached their positions except by transportation. The great majority of these boulders were trap, many were hornblende gneiss, a few sandstones, granites, slates, and occasionally a limestone or grit "wanderer," whose absolute irrelevancy to its surroundings was shown in the fossils it revealed.

Such less frequent stones as contained fossils were examined by members of the Natural Science Association, and they proved their derivation from the sedimentary rocks of the north and west. The Potsdam sandstone, the Hudson River shales and slates, the Lower Helderberg limestones, the Oriskany and Schoharie grits, the Hamilton shaly limestone and the Upper Helderberg, had representatives among these intruded masses, and the most sceptical could not withstand such irrefragable evidence of removal and transferrence.

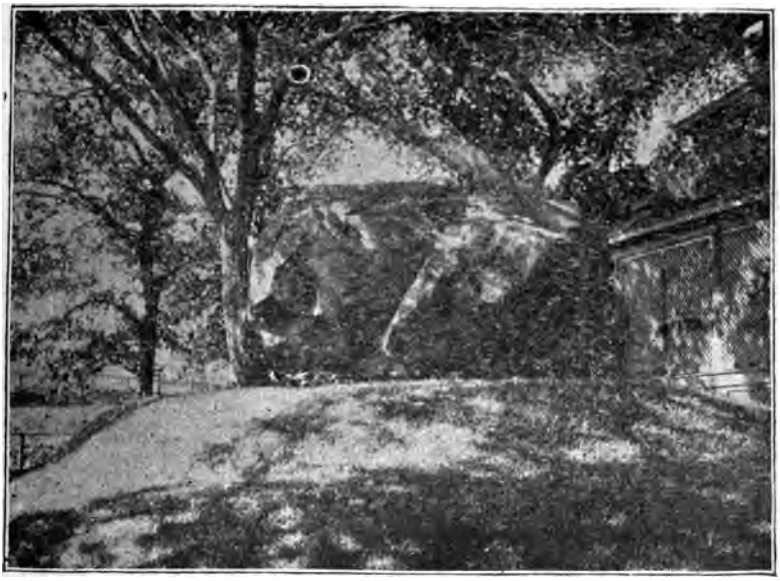

Fig. 22.—Granite boulder at Pelham Manor, Westchester County.

A stone fence or stoned gutter or a curb would often tell the observant pedestrian many instructive facts. I recall on Staten Island such a spot, the boulder paved curb and gutter of a pleasant villa on the brow of the hill at Pleasant Plains wherein granite and granitoid gneisses, quartzites, traps and sandstones mutely proclaimed their foreign extraction. Indeed, looking at this array of "sermons in stones," the impression of wonder grew as the utterly foreign nature of most of these erratics became more conspicuous by contemplation. Some of the granites came possibly from New York Island, but many were characteristic highland rocks, the hornblende gneissic granites which have been so well characterized by Britton and Merrill as the unmistakable nucleus of the highlands were here present. Here also were granulites or mixtures of quartz and feldspar, while the traps and sandstones told at once the distant seat of their initial appearance in the world's geological history, viz: northern New Jersey.

A very striking and effective boulder may be seen south of the turnpike road, now traversed by a trolley line running to Silver Lake, in the middle of a sloping field, at Stapleton, and immediately opposite the paper mill, (Fig. 23). This huge monolith of granite measures, in the pyramidal portion exposed above ground, six feet by twelve feet, by eleven and one-half feet, and if fully revealed would probably measure one-quarter more. It contains strings of tourmaline crystals.

Fig. 23.—Granite Drift Boulder, Stapleton, Borough of Richmond.

Long Island, that narrow fork of land running eastward and separated from the southern shore of Connecticut by the Long Island Sound, a shallow and turbulent trough, is lined, alike on its southern and northern edges, with boulders, while its backbone of low hills is also strewn with their *debris*. They occur gathered together in groups forming topographical features in the landscape, and single ones have a weight of 2,000 tons. As regards their origin they seem to have drifted from three localities, from the Helderberg Mountains in North New York, from Manhattan Island, and from various points in Rhode Island, Connecticut and Massachusetts. Those about the east end of the island may be traced to the Eastern States lying to the north, while many of the western visitors appear to have approached along the valley of the Hudson from the highlands of New York.

The transportation of boulders from the north southward is an incident in the general movement of all varieties of abraded and drifted material, carried on the surface of the glacier, pushed slowly forward on its edges, or still more slowly urged on beneath and in the glacier itself. Extending over centuries, this gradual *creeping* southward of the comminuted and coarse rock stuff has finally culminated in a heaping up at *about* the furthest limit of the ice sheet, of an irregular ridge or broad chain of hills and mounds, where the gathering deposit has reached its highest limit. This limit has been called the "Terminal Moraine" in direct analogy with those accumulations of earth and stones which mark the ends of existing glaciers. It is an amazing landmark. The amount of detrital matter embraced in this long sheet is stupendous, and when we inspect its contents, the smoothed water-worn or rounded stones —cobble stones—the fine sands, pulverized rock and imbedded boulders, the exact conception of a continental ice mass or glacier, adequate to accomplish these results becomes difficult, and we naturally turn to the contemporaneous picture of Greenland, buried under an "ice-cap," as a suggestive illustration.

The "Terminal Moraine" is properly referable to the aspect of the drift illustrated in the boulders, and it is itself the most heterogeneous collection of transported material. It is the final outpost of the ice-sheet in its invasion of the northern hemishere. It presents a wide belt of interblending hills, or one long ridge with slopes more gently declining on its southern than northern side. It reaches beyond Cape Cod into the Atlantic, where it has been submerged beneath the ocean by the subsidence of the land, and is traced in Nantucket, Martha's Vineyard, Block Island, Long and Staten Islands, thence ascending to the northwest, traversing New Jersey and so on over Pennsylvania. In the neighborhood and within the limits of New York city it is well developed.

The great "backbone" of Long Island is a section of this moraine, and at Jamaica and in Brooklyn its cobble-stone laden and boulder-invested mass can be easily studied. Such an exposure of the moraine is well shown to-day in an intersection of it by Underhill Avenue, north of the water-tower at the west entrance of Prospect Park (Fig. 24). Let the observant teacher take the class to the Grassmere station on the Staten Island Railroad, and walking south and east surmount one of the many intermingling hills which cover this region and which, almost treeless, reproduce a moor-like expanse, over which the eye or the feet can wander with tireless interest.

The visitor to this peculiar region not devoid, even in its barrenness, of a certain scenic charm, must not draw the inference that the rising and falling land, spread before him in hill and valley, represents the appearance which it bore when the ice, finally retreating, left it a heavy and high ridge of debris. It was then far higher more dike-like, and with a more approximately regular surface. Rains have torn down this rampart, and drainage lines becoming established, the whole original wall has been divided up into low, pyramidal hills. The morainal matter has here undergone some reassortment by water washing, and clay and sand-layers indicate a partial re-sifting and re-sedimentation. There are few large boulders, and the coarse gravelly and stony soil supports a meagre vegetation.

Fig. 24.—Boulder Drift, near Water Tower, Prospect Park, Brooklyn.

This terminal moraine touches the shore of Staten Island at Prince's Bay, where about one-half a mile from the Dental Works, the exposed face of the morainal hill is well shown under the light house, broached by storms, and exposing its stony contents. It is a hill of gravel, sand and earth with but few large boulders which, occasionally released, lie scattered over the beach. The highest point is at the light house, where the bluff has an altitude of about seventy-five feet (fig. 25). It declines landward into an undulating plain which largely represents drift re-assorted by water. This aspect of the drift is quite contrasted with the exhibitions of its *unmodified* character seen on Long Island and alluded to above. A very admirable demonstration of this latter is afforded by the cut, for instance, through which the Coney Island Railroad passes, on an ascending grade, from Bay Ridge. The hill also at Prospect Park was, not many years ago, far more extensive, covering the tract through Park Place. It is gradually being lowered, and the numerous cobble-stones recovered from it are broken and crushed and used in asphalt pavements. The iron and lime in the morainal mixture frequently form a cement and bind into rigid comglomerate

Fig. 25.—Terminal Moraine Hill, Princes Bay, Borough of Richmond. Wall at foot is artificial.

the pebbles and cobble stones. The relative positions of the included stones often show the absence of re-arrangement of the moraine by water since the heavier stones remain in zones above the smaller and lighter ones below.

It will repay the teacher to take a handful of the smaller fragmental material of the moraine and, washing the earth or clay from it, note, under a hand-glass, the stone particles remaining, and attempt an enumeration of their kinds.

GLACIAL GROOVES, SCRATCHES AND STRIÆ.

The distinction implied in these terms is one sensibly expressed in the differing meanings of the words themselves. The *grooves* are the deeper and broader scratches, the *scratches* the more obvious striæ, and the *striæ* the faintest witnesses of the ice passage, fine linings and half evanescent strains of polish.

On Manhattan Island the grooves over the hard rock surfaces are as universal as the boulders so frequently found near them. In Dr. Gale's examination the record of grooved surfaces challenges our admiration from the persistency of their occurrence, for whenever the rock was uncovered, exposed, in all probability, for centuries to rain and frost and heat, these extraordinary rulings remain, altered, of course, partially erased, but never obliterated. A few examples of these early notes are of instructive interest. It may be premised that the gneissoid rocks of New York are not the best arranged or composed mineral aggregate for the preservation of these grooves. The decomposable character of the mica and feldspar, their considerable permeability to water, and the varying hardness and denseness of the rock furnish a poorer surface than more homogeneous rocks, as sandstones, limestones and fine-grained granites, so that the grooves, scratches and striæ over the gneisses and mica schists of Manhattan Island undergo a gradual blurring, and are best preserved where the rock is more siliceous and more dense.

At 70th Street and Tenth Avenue, Dr. Gale records abundant drift grooves and scratches, in direction N 35° W.; again, at 77th Street (same avenue), "numerous, and extending almost everywhere, in favorable situations into the river even below the lowest tide-water marks, and again to the highest elevations on the island." Again on the Bloomingdale Road, between Bloomingdale Village and Manhattanville, where the rock rose seventy feet above the Hudson, the whole surface, over four thousand square feet, was scored with grooves from half an inch to an inch in depth, from one to six inches in width, and from forty to sixty feet in length. North of this were many more, some reaching three inches in depth, so that, in fact, for thousands of feet over the rock at the water's edge and on the highest points he records the omnipresent grooves.

Grooves are yet traceable on the rock shoulders above Morningside Park, south of 118th and 120th Streets, but strong channelings are reported from 163d Street and St. Nicholas Avenue.

On Eighth Avenue, Dr. Gale observed grooves at many points, and speaking of 58th Street, now continuously built over, he says: "Grooves are distinct and wonderfully so, for a diameter of two hundred or three hundred feet, in every direction, all in fair view of the road, and on the northeast side the grooves cover almost the whole rock, but are most apparent on the west side, and this last remark applies equally well to all the grooves on the island." The observation as to the greater legibility of the grooves on the west side can be clearly understood when it is recalled that the ice advanced from that direction, and impinging on the island rocks, first on the west, scored them there with their deepest impressions.

Dr. Gale calls attention to the fact that the Manhattanville gully at 130th Street is exactly in line with the glacial grooves. Through this pass was pushed an ice tongue which was instrumental in collecting the stony debris investing Harlem plain, while it wrote its signature in furrows and scratches on the neighboring or bordering gneiss ledges. As far east as Third and Second Avenues he records the grooves, and especially at those points where in his day (1838) the rocks rose steeply, as at Elisha Mott's quarry, about 37th Street, where the summit was sixty to eighty feet above tide.

Although many of all these rock surfaces mentioned by Dr. Gale have now succumbed to the invasion of the city's progress, glacial grooves are still easily found, and unmistakably recognized

Fig. 26.—Granite Boss, Bronx Park, showing glaciation.

over the rock surfaces of the island. A capital example on the very edge of the sound was formerly visible on the shore, near Travis Island, the home of the New York Athletic Club, east of New Rochelle. When I saw these, some six years ago, the earth and carpet of grass had just been removed above them, and they appeared surprisingly fresh and distinct.

In Bronx River Park and over the smoothed surfaces of gneiss which are there so conspicuous, grooves can be traced. But one example of striated and eroded granite, near the river valley, is particularly impressive. (Fig. 26). This block of granite, raised most noticeably, towers above the surrounding rock and is on a hill slope, which perhaps has partially saved it from reduction. It is marked by glacial contact; its smoothed and rounded shoulders show the polishing influences of ice passing over it. But on the southeast corner there (in fig. at the position of the human figure) is a well defined semicircular recess cut in the rock. This has been formed by ice. It is a section of a pipe-like furrow which seems shaped, rather oddly, on the side of the granite shoulder least exposed to attack. Its character is unmistakable, and the waved crown of the granite itself announces its experience with the abrading agencies of ice.

Fig. 27.—Glacial channels, Central Park, lower common, west entrance, 59th St.

In Central Park there are many localities where these grooves appear, while the smooth, rounded and generally softened lens-like appearance of the emergent swells of rock are an incontrovertible witness to ice pressure and grinding. There are very distinct grooves on the sloping rock at the side of the footpath below the summer house near the Belvidere. Here, also, rock surfaces have weathered in rough, knobby, protuberant faces from which the traces of grooves have completely disappeared. There are grooves and broader scooped hollows on rock domes in the Ramble. Rudely discerned wave furrows, disappearing eastward, on a much weathered rock on hill-top above the lake, north of the grove of Gingko trees. Near the granite boulders on the south side of the "sheep pasture," at the walk, are two scarcely emergent swells of gneiss well covered with scratches and broader gouges. These are excellent and clear. West of this, on the asphalt walk near the West Drive, are two pared and ground surfaces of rock full of glacial grooves and scratches, many nearly two inches broad.

But it is on the southern edge of the Ball Ground (Lower Common) that the most magnificent examples of glaciation are to be seen. Here are broad, deep channels on the east and a series of slanting, strongly marked, polished and twisted grooves ascending into faces of sandpapered rock on the west. The direction is quite deflected from the general slant of the grooves elsewhere. Here the direction is much more northern. (Figs. 27 and 28.) The ice

Fig. 28.—Glacial Grooves and Glaciated Rock, Central Park, lower common, west entrance, 59th St.

foot has struck this inclined face of gneiss and, being lifted up by its resistance, has gouged out these undulating gutters. In the photographs reproduced here, the boys limit on either side the width of the deep channels, and the urchin in the centre is seated on the high medial ridge or wave. The grooves in the second are almost two feet across from crest to crest, and are themselves enclosed on the floor of what appears to be a very wide gigantic glacial cut or tunnel. On this spot, or from the text it so appropriately furnishes, the teacher could make his or her pupils realize very quickly what the ice has done in planing and chiseling the rocks, and near at hand, on the west of the meadow, are also some more "wanderers," as a further reinforcement of the story.

If the teacher will visit Mt. Tom (fig. 29) at the foot of 83d Street and North River in the Riverside Park, the northern exposure shows a group of furrows near the grassy embedment of the rock, passing over it, while broad, plate-like depressions, obscurely recognized, perhaps, have been excavated over its surface. Immediately south of it is a companion knob which has lost its rounded symmetry from blasting, but which is also scored and unevenly impressed, (Fig. 30.)

Fig. 29. —Mt. Tom, Riverside Park and 83d St., showing smooth glaciated dome, and at the foot of the rock, glaciated grooves.

There need be no confusion in the mind of the observer between the glacial grooves, striae impressions, etc., and the deceptive linings of the almost vertical gneiss sheets. The cavities, hollows, long gutters, etc., which frequently run for considerable distances over the face of the gneiss arises from unequal weathering, and have no relation to the glacial grooves. This is seen quickly when the difference in direction is taken into account, the glacial grooves and wearings sweeping over the gneiss almost at right angles to the latter. Fig. 30 shows this distinction most plainly.

Besides such impressions as the rocks show, the stones taken from the drift are frequently finely scored, the scratches passing usually from end to end along the longer axis of the stone. These pebbles are, as might have been expected, quite irregularly lined, the movement of the pebble itself exposing it to abrasions in many directions, quite unlike the immovable rock surfaces over which the glaciers have swept in one but slightly deviating path. The likelihood to mistake is far more increased in the case of these scratched pebbles than even in the grooved rocks, as the creases of decay simulate the glacial striae. The indications are unmistakable when the stone presents its face or faces scored by a series of parallel cuts that resemble the incision of a gouge or stone pick. The hardness of the stones, and even their shapes, have considerable influence on the retention of these cuts. The softer or more friable stones, as the sandstones, lose these scratches more quickly than the harder,

Fig. 30.—Glaciated Rock-pinnacle in Riverside Park and 82d St. showing glacial scratches and grooves crossing rock crevices.

denser rocks, and the long, flatter stones are more usually engraved than the rounder forms.

The teacher will also find plentiful evidences of the ice-sheet in the neighboring highlands of the Palisades where the uncovered surfaces display the immemorial etchings of the continental glacier. Prof. I. C. Russell, in his "Geology of Hudson County, New Jersey," says: "Wherever the superficial material is removed from above the trap-rock in Hudson County, we invariable find the surface of the hard crystalline rock smoothed and polished and all the