GEOLOGY

OF THE

CITY OF NEW YORK

WITH NUMEROUS ILLUSTRATIONS AND MAPS

BY

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PREFACE

THE Third Edition of the Geology of the City of New York is much enlarged over the Second: first, through the necessary additions of further geological studies of Manhattan Island by various investigators, and second, through the desirable extension of the geology of Brooklyn Borough, which is made the justification of epitomizing the geology of Long Island.

The mineralogical detail has been more fully given, and, in a few expository sections, brief outlines of the Second Edition have undergone apposite elaboration.

The author acknowledges the courteous assistance of the United States Geological Survey, by valuable loans of original drawings; that of the State Geologist of New York, through his permission to copy an outline map of a hypothetical glacial condition on Long Island, presented by Professor J. B. Woodworth; and that of Dr. Wallace G. Levison, in the use of plates to illustrate his unique find of Chrysoberyl on Manhattan Island.

Recent contributions to the geology of the crystalline rocks of southeastern New York by Professor Chas. P. Berkey has brought into prominence views of the ordinal position of the Manhattan rocks, substantially in agreement with those held previously in the Second Edition of this work, and here reiterated. These rocks, instead of representing an ordovician and silurian placement, are referred, by that distinguished investigator, to pre-Cambrian sediments, which, in a chronology not easily anywhere made certain, allies them to archæan or azoic formations. Another moot question settled by Professor Berkey is that of the interlamination of the limestones with the schists, which also corroborates a provisional claim previously made in these pages.

With the disappearance of the topography or, at least, the removal of shallow superficial features of Manhattan Island, through building and construction, the opportunities for geological study, and especially for mineralogical examination, grow sensibly less. A record, then, of the known investigations in these subjects has a timely relevancy, at the moment when such investigations must be summarily curtailed. At the same time hitherto inaccessible areas have been reached, by reason of the excavations, tunnelings, caisson sinkings, soundings, etc., which accompany the new engineering enterprises on the Island of Manhattan, and elsewhere, within the limits of the greater city. The conclusions drawn from the additional knowledge gathered from such undertakings demand, too, a popular interpretation and currency, and, from its retreat or sepulture in technical treatises and proceedings of societies, the information, carefully collected by scientific observers, consciously craves, we might say, greater popularization.

The facts presented and the statements made have been brought together from many sources and are carfully classified, and the book will, it is hoped, helpfully develop and complete a correct geological conception of Greater New York.

CONTENTS

ILLUSTRATIONS

MAPS

INTRODUCTION

NORTH AMERICAN GEOLOGY

WHEREAS the geological growth of Europe presents the record of an archipelago of forming points, with continental or semi-continental areas to which they were referable, slowly consolidating into a continuous surface, the corresponding geological development of North America presents contrastedly a picture of consecutive additions to a nucleal and primary framework. Its geological history in outline is more simple. The preponderating initial land surfaces were, at the north, with longitudinal alignments along the eastern and western edges of the continental uplift, with a few interior centers of elevation (Missouri, Minnesota, Wisconsin, Texas, Dakota); and the sequence of the appearance of land surfaces was from the north southward, and laterally east and west on the borders of the two long descending ridges defining the sides of the continent, as against the submerged and cavernous troughs of the Atlantic and Pacific oceans.

In the geological history of Europe we are confronted with a series of slowly filled-up basins converted into land surfaces. In America an early architectonic outline of a primordial continent appears with two limbs stretching southward. These enclose a broad and shallow basin more open on the west, whose floor underwent secular changes of elevation and depression. Generally these changes enlarged the land surfaces, progressively through geological time, from north to south, and inwardly on the edges of the two limbs, while on the extreme east and west the continent also grew outward, in an encroachment on the Atlantic and Pacific oceans. The sedimentation which built up these areas was originally derived from the primary rocks and from the débris of the calcareous parts of sea-animals. Much re-sedimentation from previously lithified (made-into-stone) sediments contributed towards the extension of the continent at interior points and along its oceanic margins, and with this were occasional injections of igneous rock. This earliest or *archæan* continent was thrown somewhat to the east, as can be seen in the reproduction from Dana's Geology (Fig. 1), with the outlying southern extensions existing as linear strips or lenticular islands arranged on

Fig. 1. Map of North America at the close of Archæan time, showing approximately the areas of dry land.

the east in axial lines that run northeast and southwest, and on the west, northwest and southeast. But these elevations, in their structural relations, define themselves as parts of a lithic block of comparative shallow submergence which stood between the two oceans—which were abyssal creases on either side of it—and from which rose these archetypal outlines of the North American continent.

The extent and parts of the archæan area on the Atlantic border are thus outlined by Professor James D. Dana: "On the Atlantic border there is the long Appalachian protaxis, extending interruptedly from Canada south of the St. Lawrence, along the higher land of Vermont; eastern Berkshire in Massachusetts; Putnam, Orange, and Rockland counties in New York, and Sussex in New Jersey, making the Highland Range, which crosses the Hudson between Fishkill and Peekskill; constituting some ridges in southeastern Pennsylvania; thence continuing southwestward along the Piedmont Belt, and through Virginia and North Carolina, constituting in the latter State the Black Mountains; thence into South Carolina and Georgia (*A* on the map, Fig. 1).

"To the northeastward, over New England to Newfoundland, there are other parallel ranges, bounding broad valleys or basins, as follows: (1) To the east of the Connecticut valley, at intervals, from Canada to Connecticut. (2) Farther east, from near Chaleur Bay, on the Gulf of St. Lawrence, through New Brunswick, southwest to the coast of Maine (including the Mount Desert rocks) and into eastern Massachusetts. (3) The Acadian Range, along western Newfoundland and central Nova Scotia; then submerged off the coast of Maine and Massachusetts; then over southeastern Massachusetts, and probably along Long Island. (4) A central Newfoundland range, which may have had a submarine extension along Sable Island and the shoals about it, east of Nova Scotia. (5, 6) Two other ranges farther east.

"The Acadian is the longest of these Archæan ranges; it is the chief eastern belt of the Archæan on the Atlantic border, and is strictly the Acadian protaxis. Its partial submergence is not in doubt; for, besides indications of this along the sea-bottom south of Nova Scotia, there is proof of subsidence of several hundred feet in the fiords of Maine and the coast, in the Bay of Fundy, in Massachusetts, and Narragansett Bays, and in *Long Island Sound.* The combination of the Acadian and Appalachian protaxes determined the existence of the great 'Middle Bay' of the Atlantic Coast (the 'Southern Bay' of Dana extended from Florida to Cape Hatteras, the 'Eastern Bay' from Nantucket Island northward), and in the region of their junction lies the *Bay of New York with the mouth of the Hudson.* Thus, the foundations were laid in Archæan time."

Spurs from the Archæanterrane reached southward in Westchester County, New York, and western Connecticut, and one of these formed the nucleal member of the Geology of New York, a peninsulated tract built outward by additions of sediments. This tract, elevated, by reason of very extraordinary superficial contraction of the earth's crust, became variously modified by metamorphism, invaded by dike rocks, and mineralized by chemical readjustment of its elements. It remained apparently unmodified, except as acted upon by atmospheric agencies and by the ice of the Ice Age, and it also remained permanently above the ancient seas throughout the long periods of geologic time from the close of the Lower Silurian to modern and recent days. But on Staten Island and on Long Island later deposits, younger than the Paleozoic, appear.

Geologic Time has been separated by American geologists into a number of subordinate time groups, each one of which, in the main, exhibits a more or less homogeneous, or at least, typical fauna, consistent with and defined by its own limits; while within a larger unit of time (Cambrian, Lower Silurian, Upper Silurian, Devonian, Carbonic, etc.), the assemblage of these more specific horizons still express a faunal stadium or stage. The chart of geologic time, prepared and recognized by American geologists, follows:

ARCHÆAN TIME.

The *Laurentian Era.*

The *Huronian* (*Algonkian*) *Era*

PALÆOZOIC TIME.

Early.

The *Cambrian Era.*

The *Lower Silurian Era.*

Late.

The *Upper Silurian Era.*

The *Devonian Era.*

The *Carbonic Era.*

MESOZOIC TIME.

The *Triassic Period.*

The *Jurassic Period.*

The *Cretaceous Period.*

(The first two become frequently continuous, and form the *Jura-Trias.*)

CENOZOIC TIME.

The *Tertiary Era.*

The *Quatenary Era.*

The broader subdivisions (within which again sections may become quite local, and, relatively, as regards thickness, minute), under the above larger groups, have been fixed in nomenclature in the succeeding order; it is understood that here, too, in these minor divisions, and more prescriptively, a faunal uniformity obtains:

Cambrian. { Georgian, Olenellus zone.
Acadian, Paradoxides zone.
Potsdam, Ptychoparia zone.

NOTE.—The *zone* names above refer to characteristic trilobitic forms found at the successive horizons.

Rocks; predominatingly slates and sandstones:

Lower Silurian. (Ordovician.)	Calciferous, Ophileta beds.
	Chazy, Maclurea beds.
	Trenton, Asaphus beds.
	Utica, Graptolite beds.
	Hudson (Hudson River), Modiolopsis beds.

NOTE.—The Trenton *epoch* has been separated into three formal strata, *viz.*, Black River, Bird's-eye, and Trenton limestones. *Ophileta* is a fossil gasteropod or coiled univalve shell; *Maclurea,* a fossil gasteropod, flat surface, with an operculum; *Asaphus,* a trilobite; *Graptolites,* fossil hydrozoans occurring as black glistening notched threads; *Modiolopsis,* a fossil bivalve, mussel-like.

Rocks; predominatingly limestones, with slates and shales in the Utica and Hudson River:

Upper Silurian.	Medina; Clinton; Niagara;	=Niagara Period.
	Salina;	=Onondaga Period.
	Lower Pentamerus; Shaly Limestone; Upper Pentamerus;	=Lower Helderberg Period.

NOTE.—This era is quite sharply divided by the Salina beds. The upper division, the Lower Helderberg, has a great thickness in the east, and disappears westward; the zoological character of the Niagara and Lower Helderberg periods is contrasted.

Rocks; sandstone, conglomerate, shales, slate, limestone, the latter especially in the Niagara:

Lower Devonian.	Oriskany.
	Schoharie and Cauda-galli.
	Corniferous.

NOTE.—The Oriskany has a distinct type, where characteristic—the fossil brachiopod *Rensselaeria,* and large bivalves and univalves distinguish it, with an absence of corals and crustaceans. The Schoharie is local or nearly so.

Rocks, sandstones, grits and heavy limestone in the Corniferous.

Upper Devonian.	Marcellus; black shales, etc. Hamilton; shaly and calcareous. Genesee; shales. Portage; sandstone. Chemung; sandstone.

NOTE.—The *Catskill* rocks are considered as contemporaneous with the Chemung, " parallel in their deposition with that of the off-shore and deeper waters of the Chemung period."—DANA.

Carbonic.	Lower Carboniferous. Carboniferous. Permian.

Triassic or Newark.	Occurs in *areas,* from Nova Scotia to North Carolina; these are long, narrow troughs parallel to the Appalachian Ridge.

Rocks; sandstones, shales, conglomerates, and intrusive dolerite (trap) dikes:

Jurassic.	United in the east with the triassic: not distinctively represented: found west in Colorado, Wyoming, Montana, Dakota, etc.

Cretaceous.	Occurring on the Atlantic border, on the Gulf of Mexico, in Texas and Mexico, and over a wide territory which embraced the top of the Rocky Mountain axis, reaching south through New Mexico; and on the Pacific.

Rocks; clays, sands, marls, limestone.

Tertiary.	Eocene. Miocene. Pliocene.	Marine and fresh water deposits.

NOTE.—Fossils approximate living species—formations largely local beds, loosely consolidated: in the west immense volcanic deposits.

Quaternary. { Glacial (Ice Age). Champlain (Pluvial Age). Recent.

NOTE.—The Ice Age has been divided by some geologists (Chamberlin, Saulsbury, Leverett) into two epochs—an early and later Ice Age—between which a reforestation of areas, made bare and desolate by the ice, took place; by other geologists (Wright, Fairchilds) the Ice Age is regarded as a continuous period, with retreat and advance of the ice cap over long intervals.

GEOLOGICAL POSITION OF THE ROCKS OF NEW YORK CITY

MANHATTAN ISLAND

(GREATER NEW YORK)

As determined by the State geologists, the rocks of Manhattan Island represent the Archæan, Cambrian, Calciferous-Trenton (*Ordovician*), Hudson River, with injected igneous masses, dikes, etc., and a superficial covering of *drift,* river muds, and sands. This assumption is controverted in the text.

LONG ISLAND

(BOROUGH OF KINGS AND QUEENS)

Basal foundation Archæan on this overlying schists (Hudson River); possible underlying Cretaceous beds, not exposed within city limits; superficial drift, shore sands.

BOROUGH OF THE BRONX

Archæan, Hudson River, Calciferous-Trenton (*Ordovician*) igneous intrusions, drift.

STATEN ISLAND

(BOROUGH OF RICHMOND)

Central hills made up of Serpentine (eruptive and metamorphic), basal crystalline rocks similar to Manhattan (now covered), Triassic shales or slates with Dolerite (trap), Cretaceous clays, drift and shore sands. For the discussion, description and distribution of these formations see following pages.

Class Directions.—The teacher should give a clear and simple account of the formations making the geological column, and explain the process of sedimentation by which they are formed. He should begin with the oldest rocks—the Archæan—the azoic. He will find immediately north of us in the Highlands an illustration of these rocks. Upon them, following south, are a series of crystalline rocks, and slates with intrusive eruptive rocks (the Cortland series), terminating in the schists of Manhattan Island and its neighborhood. The Archæan rocks following the geological scale are overlaid by the Cambrian beds, typically represented in the Potsdam sandstones of northern New York, and supposed to have some sort of equivalent in the Lowerre (Poughquag) quartzite or quartzose gneiss at Yonkers. Over the Cambrian are laid the Ordovician beds, represented in New York State by the Calciferous Sandrock, Chazy, Bird's-eye, Blackriver and Trenton limestones, formerly known as Lower Silurian. Of these the Inwood (Stockbridge) limestone is supposed to be the equivalent of the Calciferous Trenton groups. Above these again come the Hudson River beds, shales, clay limestones (Cincinnati), etc., which it is assumed are represented on our island by the Manhattan schists and gneisses, their much metamorphosed representatives.

THE CRYSTALLINE ROCKS

The most significant and interesting formations in the New York City series are the crystalline rocks. These are bodies of mineral aggregates in which the component parts are separable minerals, and they are almost exclusively gneisses, schists, granites, and limestones. The same rocks and, it may be conceded, the same formations extend over western and northern Connecticut, where the formations, as given by Prof. H. E. Gregory, are the Becket gneiss, considered as a pre-Cambrian complex equivalent to the Fordham gneiss of the New York quadrangle; the Poughquag quartzite (found in the Borough of the Bronx), of Cambrian age; the Stockbridge limestone, of Cambro-Ordovician age, made referable to the Kingsbridge limestones on New York island; the Berkshire schist of Upper Ordovician age (Hudson River), and represented in the prevalent Manhattan schists and gneisses.

The mineral composition of these rocks embraces quartz, mica, feldspar, hornblende, dolomite, with a numerous assemblage of accessory minerals, and displays contrasted or varied aspects of texture, solidity, or position. They are related to the extended development of the crystalline rocks in New England, which, if regarded as original sediments, shore deposits, or unconsolidated mineral accumulations, have put on a lithological phase of construction in which their first or earlier state and stratification have completely disappeared or been radically modified. This change has supervened through the agency of metamorphism. As Prof. H. E. Gregory has said: "An explanation of sedimentary rocks requires a knowledge of the forces operating at the present time *on the surface of the earth;* it is necessary to understand the action of rivers, wind, ice, etc.; a complete understanding of the *crystallines* involves a knowledge of the forces which are at work *within the interior of the earth,* as well as an understanding of the chemical and mineralogical composition of the rocks as they exist."

The development of such crystalline masses means a long history. If the original sediments were muds or granular mineral aggregates, or if the original rocks were lavas, they underwent initial changes into crystalline complexes, which again under strain, pressure, and heat, assumed new mineral constitutions. The mineral feldspar can become changed into quartz and muscovite mica, or, with added magnesium and iron elements, into quartz and biotite mica, or into quartz and chlorite, the free quartz in such cases being supplied by the large percentage of silica in the feldspar (65 per cent.), exceeding by almost 20 per cent. the amount of silica necessary for the chemical composition of muscovite.. Hornblende is changed to biotite and chlorite, and again, secondarily, to zoisite and epidote. The mineral augite changes to hornblende, and it is thought that by addition of needed elements a dolomite (the carbonate of calcium and magnesium) can become hornblende, a variable silicate of aluminum, iron, calcium, magnesium, and the alkalies. Throughout these *metamorphoses* the mica minerals retain permanency or are an ultimate term in the transitions.

The pressure, almost inevitable as an agent in these changes, gives flatness and parallelism to the resultant minerals, and the schists and gneisses which contain them are banded, fissile, laminated, splitting into rudely smooth leaves or cakes or exhibiting *schistosity,* which in the very compact slates becomes *fissility,* whereby the slate rock cleaves into thin and useful plates.

The minerals that play the most conspicuous part in the structure of the crystalline rocks are the feldspars (silicates of aluminum, calcium, potassium, and sodium), quartz (oxide of silicon, silica), the micas (silicates of aluminum, magnesium, potassium), and amphibole (hornblende), with pyroxene, the last two related minerals having composite compositions (for the most part silicates of aluminum, calcium, magnesium, and iron).

Among the crystalline rocks granite takes a prominent place. It is quite noticeably contrasted with the gneisses and layered rocks from its massive and heterogeneous texture. Its component minerals are not arranged in sheets, but are irregularly intercrystallized and interlocked, though, under pressure again, granites become granite-gneisses and assume schistosity. Granites are contrasted with the gneisses as massive rocks, made up of feldspar, quartz, and mica, which are mixed together and intercrystallized with accessory minerals. They are regarded as eruptive, the cooled and crystallized magmas which have been forced upward from underlying sources into the areas above heated, pasty reservoirs, or pushed out and injected as dikes, apophyses or arms into cracks or openings of the invaded beds. Granites appear in the rocks of Manhattan Island, and are referred to igneous protrusions, though it is not inconceivable that minor veins and tracks of so-called pegmatized gneiss have resulted from a refuson of the metamorphic gneiss in the development of heat from frictional movement, under stress and plication, upheaval, distortion or compression, and through the action of included water. In this way the gneiss became saturated with granitic lenses, fillings and streaks drawn out in parallelism with the enclosing gneissoid envelopes, upon the folding or elevation, under pressure, of the entire complex. Some granite veins suggest segregation or water-filling.

The crystalline rocks of Greater New York have been deeply compressed, and their original horizontal extension may have undergone a contraction of more than a mile, which was the result of crustal shortenings over the whole of the earth's sphere. Of course the effect of such a contraction would be to throw up the more or less horizontal beds into hills or mountains of inclined strata, bringing about at the same time internal mineral changes and structural changes connected with the metamorphism of the beds. (See section on Metamorphism.) Such horizontal contractions have been considerable in the geological history of the earth. De la Beche has shown that contorted and inclined beds would require, if reduced to a level surface, much more room, and that if stretched out into flat sheets they would invade adjoining areas. Professor Heim, of Zurich, computed that the Alps, toward the north, have been thus compressed, and the horizontal shrinkage of the superficies of the earth at this point has been something like seventy-four miles, or "one-half of the original horizontal extent of the component strata, which have been corrugated and thrown back upon each other in huge folds, reaching from base to summit of lofty mountains" (Geikie).

Such a contraction in the New York area has resulted in the upward projection of high hills, or monticules, which may have attained altitudes of over four thousand feet, and which have disappeared through prolonged weathering, leaving the present inconspicuous relief of the surface. This merely mechanical or local elevation has been accomplished slowly, though even that slowness of ascension probably was associated with *periodic* movements, and it has been exaggerated or reduced by continental uplifts and depressions. In these hills the stratified beds or their metamorphic equivalents have been thrust up on end, or at steep angles; shearing forces have been exerted upon them, and included igneous intrusions have participated, along with their enclosing schists, in the folding and plication, and there has not been wanting readjustments by faults and dislocations.

Fossils within the limits of Greater New York are found, *in place,* only in the Cretaceous beds of Staten Island (Richmond borough), though the drift areas, in which occur transported boulders from fossiliferous horizons in New York State, have furnished an interesting and extended series.

METAMORPHISM

The teachers in the schools may have some real or fancied difficulties in understanding metamorphism. Perhaps in all its phases and in the minutest intimacy of its mineralogical process, few or any of the lithologists may be said to exactly understand it. It is a process of conversion. By it mixtures of sediments containing alumina, magnesia, lime, iron, potash, soda, boron, fluorine, phosphorus, silica in various proportions, and generally assembled in place under the form of clay or calcareous or arenaceous muds and sands, are changed to hard, stony rocks with the development therein of many minerals, those so familiar to the teachers in crystalline rocks as garnets, tourmaline, andalusite, fibrolite, staurolites, quartz, cyanite, amphibole and pyroxene, and many more, enclosed in mica schists, gneisses, slates, quartzites, etc., while by it also lime muds become crystalline limestones. It must be recalled, however, that such muds, clays, etc., may have had in them much crystallized material.

A rude and yet helpful conception can be gained of it by considering how the soft dough, under heat, the expansion of included gas, and prolonged standing in these conditions, becomes the more or less hard and brittle bread. The soft clay put in the furnace, shaped into the form of various utensils, is similarly metamorphosed into the ringing, dense, stone-like ware. Such illustrations fall very far short of accuracy, and yet they impose upon the mind at least this idea of a physical hardening, in which new densities and new chemical combinations, or assortments of combinations, take place in the hardening body. In fact, in nature it is most likely that in all instances of metamorphism there has been a mineralizing process going on, in which heated waters have penetrated the hardening, crystallizing menstruum at the beginning, at the middle, or even at the end of the metamorphic action, and have not only assisted the mobility of the mass of sediments, but have brought to it new elements.

Such metamorphic action can be greatly varied. It can be, as regards time, slow or more rapid; as regards agencies, it can arise from earth movements or from the proximity and intrusion of lavas rising from deep-seated sources; as regards phase, it may be complete or incomplete, the former indicating a condition of more mineral complexity or alteration.

All sedimentary deposits are more or less filled, in the interstices, with water, which as a universal solvent is never free from dissolved substances. This water heated becomes active in its solvent powers, and, as the beds are compressed, lifted and hardened this water begins a mineralizing influence throughout. Pressure and heating continue, and while not probably at high temperatures, at least, at first, a rapid mineralization goes on. The elements sort out into compounds, as silicates, of which those most readily formed are the most numerous. A semi-fusion succeeds and, the pressure continuing, a schistose structure is developed, the longer axes of the flakes and crystals lying together along the planes of the rock cleavage. Such beds exhibit plication and folding, and there must have been a sensible plasticity permitting the innumerable major and minor flexures. Should the beds become rigid, the folding process results in faults and fractures. Shearing or long strains and movement along certain planes aid mineral changes, developing heat, and thereby causing secondary solution and redeposition. The mica schists result from clay beds infused with potash or iron waters, with magnesia salts, such as might readily remain in beds laid down in sea-water. Silica, so universally distributed in gneissoid rocks, has been brought up in heated waters or separated out from the original mass of sediment, where it may have been a sand, as a crystalline unit.

There is both local, or contact, and regional metamorphism, the former occurring around intrusive dikes and bosses, as in Norway, in the Harz, in Scotland, in New England, and the latter, extendedly developed over a whole area, subjected to secular crustal motions and shortenings, as on our island. As a true metamorphic instance the conversion of a soft coal seam into natural coke by an intruded rock may be alluded to. The metamorphism of calcareous muds, making of them marbles, is practically a baking, a change of structure, of density, etc., with a probable accompaniment of developing silicates, as tremolite, tourmaline, phlogopite, diopside, etc.

Progressive metamorphism denotes a consecutive increase of crystalline structure and contents, as when clays baked into slates develop, under further metamorphic stress, chiastolite, quartz, mica.

Besides the metamorphism of sediments, there are so-called metamorphic changes in igneous lava-like bodies which come up through crevices in the earth's surface, and are essentially natural slags or glasses. Their metamorphism consists—after their consolidation and crystallization—in mineral changes, whereby also under pressure, shearing, etc., and by mineralizing agents as water and fluorine, new minerals develop or old ones enlarge, and the unstratified magma becomes foliated, zoned and schistose. It is an inverted metamorphism.

A superb example of all gradations and sorts of metamorphism is found in the Chester amphibolites and serpentines of Massachusetts. The series (Emerson) consists of amphibole rocks, pyroxene rocks, enstatite rock, serpentine, dolomites, and steatites, and can be traced from the Hoosac Tunnel across the State. It is filled with granitic intrusions, and both regional and local (contact) metamorphism are displayed. Professor Emerson says, where the granites are present, "the intenser metamorphism of the schists is indicated by their coarser crystallization, the lack of sericite, and the great abundance of cyanite, which, of all the purely aluminous silicates, indicates the strongest metamorphic agencies."

A capital example in these Chester series of the effect of heated water solutions (which makes up a stage in the metamorphism) are the enstatite beds (silicate of magnesia with iron), which Emerson concludes were formed from a somewhat ferruginous dolomite "permeated by heated siliceous solutions set in motion by the large granite batholites upon their intrusion into their present positions." This resulted in the formation of a ferruginous silicate of magnesia, or enstatite.

Take one other example from the same classic region, the famous Chester Emery Bed. It seems to Prof. Emerson that the emery magnetite vein was "originally a deposit of limonite, which was formed by the replacement of limestone," and into which alumina was carried. Metamorphism then formed magnetite and corundum (emery), and with silica the corundophyllite (a greenish mica-like mineral composed of silica, magnesia, alumina, iron). That was the first generation of minerals. The corundophyllite continued to be formed in the abundant fissures "produced by the continued intestinal movements of the mass," along with tourmaline, epidote and pyrite. That was the second generation of minerals.

The corundophyllite continued to form in larger plates with rutile, brookite, menaccanite, calcite, diaspore, margarite, and epidote. That was the third generation. The fourth "stadium" consisted in the formation of specular iron, aragonite, calcite, which "indicate the presence of steam or heated waters and gradually cooling waters in a new set of fissures." (Geology of Old Hampshire County, Massachusetts, Benjamin Kendall Emerson, Monographs, U. S. Geol. Survey, Vol. xxix.)

In the metamorphism of the Manhattan beds there was, first, consolidation of sediments, formation of minerals; second, disturbance, slight pressure, and development of more minerals, and the granitic veinlets, lenses, or the so-called pegmatized gneisses; third, mountain-making movements, uplifts, crushing folds, etc., and slow protusion of granite dikes and, of course, more heat and more minerals.

This topic may be instructively dwelt upon a little longer. Metamorphism involves (1) a change in physical condition, as from soft to harder rocks, as from shales to flinty hornstone, uncrystallized to crystallized rocks, as from limestone to marble; and (2) a change in mineralogical aggregates, as when andalusite is developed in slate, garnet, tremolite, tourmaline, in limestone, tourmaline and quartz in schists.

The eruptive rocks which have invaded limestones in the Tyrol (Monzoni, Predazzo) have developed a series of adventitious minerals, as garnet, idocrase, spinel, anorthite, mica, apatite, magnetite, etc. Some of these occur, however, only in the eruptive masses. There has been here a *reaction* between the invaded and invading rock masses, and a, so to speak, dry precipitation of new mineral bodies, sometimes meaning a rearrangement of the chemical elements, or a rearrangement with *additions* of new chemical elements. In the fossiliferous zones of the Christiania district of S. Norway the eruptive granitic rocks have produced horny, flinty rocks from the limestones and shales; cement stone is changed to garnet; sandy layers have become quartzites; *non-calcareous* clay slates are altered into chiastolitic schists; biotite mica has been developed in the limestone—*and yet the fossils are not completely obliterated.*

An excellent example of progressive metamorphism from the Lake District in the north of England is thus delineated by Geikie: "The slate where unaltered is a bluish-gray cleaved rock, weathering into small flakes and pencil-like fragments. Traced toward the granite, it first shows faint spots, which increase in number and size until they assume the form of chiastolite crystals, with which the slate is now abundantly crowded. The zone of this andalusite-schist seldom exceeds a quarter of a mile in breadth. Still closer to the granite a second stage of metamorphism is marked by the development of a general schistose character, the rock becoming more massive and less cleaved, the cleavage planes being replaced by an incipient foliation due to the development of abundant dark little rectangular or oblong spots, probably imperfectly crystallized chiastolite, this mineral, as well as andalusite, occurring also in large crystals, together with minute flakes of mica (spotted schist, *knotenschiefer*). A third and final stage is reached when, by the increase of the mica and quartz-grains, the rock passes into mica-schist—a light or bluish-gray rock, with wonderfully contorted foliation, which is developed close to the granite, there being always a sharp line of demarcation between the mica-schist and the granite."

In the French Pyrenees and in the Eastern Vosges similar progressive changes in the clay-slates are traced towards the granite, being at first colored and fissile with quartz stringers, then growing spotted, lighter in color, and harder, with swarming mica plates, then graduating into a ringing stone, highly crystalline and made up of andalusite quartz and mica. (Andalusite, as a silicate of aluminum, naturally is an end product in these changes from an original clay bed.)

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 archæan nucleus of Saxony.

The justification of assigning the Manhattan Island schists to metamorphosed Hudson River slates is doubted.

Again, Albert Heim has indicated the extreme physical changes brought about in sediments by mountain uplifts and compression: "Enormous zones, for instance, in the interior of the Finsteraa *massif*, that were formerly held to be true crystalline schists, prove to be originally plastic rocks of the carboniferous period that have been squeezed into schists and pervaded by secondary mica. Conglomeratic rocks of the Verrucano group and clay-slates nipped into the *central massif* have become crystalline schistose, and even gneissose. They can scarcely be distinguished, in the field and in the hand specimens, from crushed gneisses pervaded by sericites. Granites can be proved locally, and perhaps also regionally, to have been compressed into gneisses. Gneisses, having a different position relatively to the pressure, have locally become granitoid. Massive eruptive felsite-porphyries have become felsite-schists. Mica-schists have been dragged out, their quartz grains ground down, and the whole converted into a rock that one would be inclined to describe as a sandy clay-slate. Even Liassic slates, with fossils, have been converted into garnetiferous mica-schists, staurolite-schists, etc. The boundary between the old crystalline schists and real sediments in the Alps has, by such processes of dynamic metamorphism, been obliterated."

Metamorphism must not be associated exclusively, or even predominantly, with the alteration of soft or unconsolidated beds of sediments. Its effects are quite as evident in rocks which have become completely solidified and which have already advanced to a crystallized or semi-crystallized stage, as in slates, limestones, and schists, sandstones, even granites, diorites, and dolerites.

A. C. Spencer has described the metamorphism of a *conglomerate* in the Encampment District of Wyoming, which is noted as almost unchanged from its original condition in some places and frequently metamorphosed in others. This action (here described as chemical and mechanical) has been carried so far that included pebbles, and even boulders, have been *mashed* into disk-like plates, and the rocks, by recrystallization, converted into a gneiss. The origin of the gneiss would be indeterminable except by a study of the gradual passage of the conglomerate to the gneiss.

Metamorphism is a chemico-physical process. Stress of mass against mass strains, the tearing apart through torsion or shearing will bring about molecular alterations in identical chemical compounds; it might change a pyroxene into an amphibole. It (metamorphism) means, also, introduction of new chemical elements or additions of chemical elements already present. It means developments of crystals, growth of crystals or crystalline fragments; it generally means recementation and densification. Metamorphic rocks are crystallized rocks, rocks also usually laminated, rocks compressed and having parting planes, cleavage, or fissile, in thin sheets; sandstones can thus become quartzitic schists, dividing up into parallel slabs, and igneous *massive* rocks banded schists or gneisses. In metamorphic rocks there is a prevalent parallelism of crystals, which, of course, helps division into parallel planes; apparently a granite may be smashed and remade, through plasticity, into a granite-gneiss. Compression or pressure seems indispensable in metamorphism, its most critical agency; the irruption of igneous rock bringing heat, mineralizing vapors and fluids, must also, most sensibly, develop pressure.

The geologist Chamberlin has defined an *anamorphic* and a *katamorphic* metamorphism, the former a constructive, the latter a destructive metamorphism. By anamorphic metamorphism fragmental sediments are made into crystalline rocks; by katamorphic metamorphism massive rocks, like granite or basalt, are crushed down into foliated forms.

The common minerals of metamorphic rocks are feldspars, micas, quartz, chlorite, hornblende, staurolite, andalusite (chiastolite), cyanite, garnet, epidote, titanite, fibrolite, calcite, dolomite, tremolite, tourmaline, serpentine, talc, pyroxene, hematite, magnetite, pyrite, while in notable instances coarse granites (pegmatites) intruded among them supply less usual minerals. On Manhattan Island Mr. W. Niven found Monazite and Xenotime (see List of N. Y. Is. Minerals, p. 139) in a granite matrix, and the granite areas have contributed the larger number of well-developed minerals.

Metamorphic *schists* are universally folded, crumpled, in wavy plications like undulating paper sheets, evidence of those squeezings and thrusts which have played an extreme part in their formation. Such titanic force has been engaged, that fracture and flowage of parts has taken place, crystals have been pulverized, and nodular stones in conglomerates stretched or elongated. In this connexion it may be recalled that experiments in the geo-physical laboratory of the Carnegie Institute have shown that crystallization can be made to proceed in silicate glasses at a temperature much below the melting point of the individual minerals, but while viscous. Thus crystallized under stress, a parallel arrangement of the crystals ensued along planes, as shown in gneisses and schists.

MINERALS AND ROCKS

A brief reference to these topics, which is not in any sense to be regarded as a substitute for a study of the larger geological manuals, is here inserted as helpful to teacher and student.

A mineral is the ultimate geological unit. All the rocks of the earth, its entire crust, are mineral aggregates, and such aggregates of minerals form in three ways: by sedimentation, deposition from water (including *organic* accumulations); by igneous effusions, the outpouring of liquid or pasty lavas, the blowing out of volcanic ash, lapilli, dust, from volcanic vents; by metamorphism, recrystallizations through heat and pressure of sedimentary and igneous rocks. Sedimentary rocks are sandstones, shales, and limestones, the first mainly bedded siliceous sands, the second compacted and cryptocrystalline (partially crystallized) clay beds, the third massive calcite or dolomite. Igneous rocks are acid or basic (*salic, femic*) combinations of silicates, the acid (salic) are granites, gneisses, trachytes, felsites and (merging into the basic) andesite, diorite, etc., *viz.,* silica as an *acid* in excess. The basic (femic) are gabbros, diabase, peridotites, etc., *viz.,* iron, aluminum, magnesia, lime, as *bases,* are in excess.

Metamorphic rocks are foliated or bedded crystalline masses and complexes. They may be pure quartzites or hornblende, mica, chloritic, staurolitic, andalusitic, cyanitic, etc., schists, and gneisses, marbles and slates.

The minerals of rocks naturally may be said to be all the minerals known to science, but practically 36 species include the inorganic material that makes up ninety-five per cent. of all known rocks. They are:

Amphibole (=actinolite, hornblende, tremolite) Andalusite, Apatite, Calcite, Carbon, Dolomite, Enstatite, Epidote, Feldspar (=orthoclase, oligoclase, albite, anorthite, labradorite); Fluorite, Garnet, Glaucophane, Gypsum, Hematite (iron ore), Hypersthene, Leucite, Limonite (iron ore), Magnetite (iron ore), Mica (=biotite, muscovite, lepidolite, phlogopite), Nephelite, Olivine (=chrysolite), Scapolite (wernerite, meionite, mizzonite), Sodalite, Staurolite, Zoisite.

NOTE.—The teacher who uses the above section should expand it, referring to the formation of rocks, their disintegration, the formation of soils, the origin of veins, the extent of the mineral kingdom, especially emphasizing the chemical elements and the nature of a *salt* as a chemical term, and mineral combinations as salts. The section is very condensed. It should be filled out with illustration, examples, pictures and diagrams. Consult G. P. Merrill's "Rocks, Rock-Weathering and Soils."

ZONES OF ROCK STRAIN

In the contraction, or assumed contraction, of the earth's crust, the stupendous strains developed will affect different rocks in a different way as they are brittle or tough, thickly bedded or in thin layers, and it will also affect them differently as they are removed at comparatively great distances from the surface. Van Hise, who has developed this principle, assumes that at a depth of 30,000 feet below the earth's surface the overlying pressure is so great that the rocks cannot break or crack under compression, but that they *flow,* that their particles adjust themselves to new positions of stability under the strain, by *movement,* that indeed they behave like soft or mobile bodies, like wax, for instance. Such movements must be infinitesimal, but as every component molecule of the rock shifts its position to accommodate the stress, the whole mass of rock has been welded and moulded like a plastic body. This is called the Zone of Flowage.

Above this zone the pressure is relieved or diminished, and the stronger rock layers will break or crack when the thrusts of compression take place; they will not then *flow,* while the weaker, less resistant rocks will flow, and the resultant mixture of effects, where some rocks yield without losing continuity, and other rocks break, represents the so-called Zone of Fracture and Flowage.

Above this zone again, and now in closer proximity to the surface, all the rocks break, and faults, joints, crevices, are formed, shatterings occur, crushings and the familiar results of smashing and even pulverization. This is the Zone of Fracture.

The rocks of New York Island suggest a complementary hypothesis. They have not been in the zone of flowage, perhaps very near it; they have participated in the strains of the zone of fracture, but they have been bent and folded, crumpled, and thrown into rippling undulations, which may be seen on their schistose surfaces like the pleats of a gown. Plication may not imply flowage. Schistose micaceous scaly structure, with myriads of small scales imbricating and dove-tailed together in a sensibly flexible texture, creates an accommodating lithic material which might not inaptly be compared to minute mail armor. Compression would here induce a slipping over each other of the component scales, and it is further conceivable that if the compression occurred at the time when the scales were forming, it would enormously facilitate the process of almost indefinite mobility, so that, without fracture and without flowage, the rock would become pliable. Even a quartzite might in this way, along innumerable microscopic slip planes, assume complete curvature. In such a process of accommodation the steps would be very gradual, and the time consumed in folding a low and broad area of sediments would be very considerable. The evidence of this slowness is furnished in the small linearly extended wavelets of plication that can be seen in the mica-schist of Manhattan Island. These were probably deeply seated. There were doubtless also axes of maximum plication, where the strata were squeezed into steeper and longer folds; such axes would assert themselves along the less resistant beds, or even where there was the deepest accumulation of deposits, and so more pressure and more material for unlift and compression. The minor folds evolved over surfaces a few square feet in width must be distinguished from the anticlinals which carry the series of beds up in almost vertical sheets (well seen in the excavation of the Pennsylvania Railroad, Fig. 2). The examination of the folded and contorted strata of Manhattan Island is well calculated to impress and instruct the observer.

By way of a supplement to the foregoing pages, the reader may be interested in a quite contrasted theory proposed by Dr. T. Sterry Hunt (a very distinguished investigator in the physics and chemistry of our earth) on crystalline schists,* which he called *crenitic,* and by which he intended, and ex-

*Nature, Vol. xxxvii, p. 519; also Dr. Hunt's book, "The Schists."

pressly said so, to obliterate the "metamorphic and metasomatic schools." By it he assumed a mineral "protoplasmic mass" which, as the result of crystallization and cooling, "had already become porous." Then followed an outflow of hot waters which dissolved and removed from the protoplasmic material silica, alumina, and potash, adding lime, magnesia, and soda, which "must have necessarily altered by degrees the composition of the porous mass, heated from below, penetrated by aqueous solutions, and rendered more or less plastic in parts. In the changing mass, moreover, took place processes of crystallization, followed by partial separations determined by differences in specific gravity between the species thus formed. In this way were produced various types of plutonic rocks which may be justly called "Primary." T. Sterry Hunt would refer the crystalline Manhattan schists to these Primary rocks. As to the gentle folds (*plicæ*) so characteristic of these rocks, he said "decrease of volume beneath the crenitic covering (the area of the schists) must have resulted in movements giving rise to the more or less marked corrugations everywhere met with in the earlier layers of the crenitic envelope." Probably this view to-day would receive little more than an antiquarian attention.

MANHATTAN ISLAND

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 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.

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 at 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 débris, 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 Street, from Hell Gate at 92d Street to Randall's Island at 125th Street and thence to 155th Street, 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 Street. 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, 10th and 30th Streets, the edges of the island were eroded and frayed by a variable fringe of marshes. The island area has been almost everywhere below 14th Street 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 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 patens*, Ait), 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

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

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 tidewater 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 careless 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."

As early as 1621 there is definite information that fruits, such as plums, wild cherries, and pears, grew wild in the woods; birds also were plentiful, particularly pigeons, which were chased by the foxes like fowls.

New York streets in 1748 were pleasantly shaded by water, beech and locust trees, lime trees, and elms, which were populous with birds, and, amusingly enough, were criticised by strangers as affording homes for tree toads, whose "clamorous voices" aroused protest.

The elevations of rock at Fort George (196th Street), Fort Washington (176th Street), the Inwood Ridge (207th Street), and the Kingsbridge hills (222nd Street) 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 Street 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 10th 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 Street.

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 to the south; then turning to the west the "noble Hudson," with the Newark mountains in the distance, the farmhouses 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 4th Street 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 Street to Front and west to Division, was broken by undulating surfaces, and some of the hills were of 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, to-day is a noticeable protuberance, swelling with a gradual rise from 34th Street, sinking towards 42d Street, and reaching from Lexington Avenue to Broadway, with an imperceptible prolongation northward, melting into the surfaces of Central Park. Here, at 42d Street and 5th Avenue, 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

*An interesting observation was made at this spot. A fort had been built at its summit, and in the center 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.

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 Street, 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 Street on the west side, and the larger creek and streamlets at its heads, running into Hell Gate at 92th 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 Street, 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 (Fig. 3), north of 59th Street, 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 8th Avenue, exhibit their nature. Besides a succession of barren folds of rock, holding pockets of débris, 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 over the streets cut through them, as between 3d and 5th Avenues above 90th Street. A base leveling, as it were, has been instituted, and except for the unavoidable undulations of the surface, its superficial characters, of course, have disappeared. On the west side, in the region of Claremont, now 116th Street to

Fig. 2. Pennsylvania Railroad Excavation, 31st Street between Seventh and Eighth Avenues, looking South.

Fig. 3. Manhattan Schist, between 79th Street and 80th Street, Columbus Avenue.

Fig. 4. Looking Southwest from 42d Street and Park Avenue Rapid Transit Excavation.

Fig. 5. Poughquag Quartzite (?) at Morris Docks.

125th Street, 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 bird's-eye view of this region from 59th Street to 125th Street 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 Street, 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 5th and 3d Avenues. Northward the transverse gorge or clove at 125th Street bending northwestwardly to 129th Street is encountered, and beyond it from Convent Avenue another upheaval carries the rocky prolongation, still rising to Washington Heights at 155th Street to 176th Street. 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 northwest 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 Street; while beginning at 89th Street, opposite the slim tip of Blackwell's Island, we encounter a rim or ledge of rock, sometimes precipitous and again retreating, continued south toward 50th Street the basement of a meridional ridge, or one running north and south, like those we have encountered, somewhat *en échelon,* 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 superficial 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 them transversely, somewhat irregularly related to the north and south lines, but still unquestionably present at Murray Hill, the fold at 59th and 93d Streets, 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, those of Manhattanville and Inwood, cross it obliquely, while a gash, or fault, at Spuyten Duyvil, subsequently eroded into a waterway, separates it from identical formations to the north. Its present features are doubtless due to comparatively modern agencies (quaternary), 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 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 Street, exposures along the East River, show the drift areas on Manhattan Island, in Brooklyn and Staten Island. (See pp. 172, 202.) 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 débris. It has progessively 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 3d Avenue and 66th Street—now reduced for the occupancy of the Elevated Railroad 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 Professor 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 Street—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 Street—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 5th Avenue; again at the Jefferson Market Court House, 8th Street and 6th 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, 5th 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; quick-sand 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 11th Streets—Sand, 40 feet; red clay, 23 feet; to rock, 63 feet.

Ninety-ninth Street and 2d Avenue—Made ground, 8 feet; dock mud, 18 feet; sand, 21 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 Building, hard pan, 71 feet below Broadway curb.

Empire Building, hard pan, 54 feet below Broadway curb.

Washington Life Building, hard pan, 75 feet below Broadway curb.

Mr. Chas. H. Deans remarks on the 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 quick-sand."

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

I owe to Engineer Chas. J. Bates the following details of borings in the lower part of Broadway, and adjoining streets:

Broadway and Vesey Street—Top earth and medium sand, 12 feet; fine sand, 54 feet; running sand, 15 feet.

Broadway and Fulton Street—Top earth, 10 feet; medium sand, 6 feet; fine sand, 28 feet; quick-sand, 4 feet; running sand, 35 feet.

Broadway and Dey Street—Top earth, 10 feet; medium sand, 7 feet; fine sand, 17 feet; running sand, 38 feet; quick-sand, 5 feet.

Broadway and Cortlandt Street—Top earth, 8 feet; medium sand, 9 feet; fine sand, 34 feet; running sand, 19 feet.

Broadway and Liberty Street—Top earth, 10 feet; coarse sand, 4 feet; medium sand, 6 feet; fine sand, 25 feet; running sand, 25 feet.

Broadway and Cedar Street—Top earth, 8 feet; sand, 7 feet; fine sand, 37 feet; running sand, 18 feet.

Broadway and Pine Street—Top earth, 8 feet; medium sand, 12 feet; fine sand, 26 feet; running sand, 24 feet.

Broadway and Wall Street—Top earth, 6 feet; medium sand, 9 feet; fine sand, 25 feet; running sand, 10 feet.

Broadway and Rector Street—Top earth, 9 feet; medium sand, 19 feet; fine sand, 11 feet; running sand, 14 feet.

Broadway and Exchange Place—Top earth, 10 feet; medium sand, 5 feet; fine sand, 10 feet; running sand, 26 feet.

Broadway and Morris Street—Top earth, 7 feet; medium sand, 4 feet; fine sand, 14 feet; running sand, 10 feet.

The above borings were made in 1891.

Along State Street the subjoined results, also given to me by Engineer Bates, have been obtained:

No. 1—22 feet 2 inches to rock through top soil, filling and river mud.
No. 2—15 feet to rock through top soil, filling and river mud.
No. 3—15 feet to rock through top soil and filling.
No. 4—12 feet 5 inches to rock through filling.
No. 5—32 feet to rock through top soil, filling, sand and gravel.
No. 6—16 feet 5 inches to rock through top soil and filling.
No. 7—20 feet to rock through top soil, filling and hard pan.
No. 8—22 feet 4 inches to rock through top earth, filling, sand, clay, gravel, and hard pan.
No. 9—12 feet 6 inches to rock through top earth and sand.
No. 10—14 feet 2 inches to rock through top earth and micaceous sand.

Dr. Wallace G. Levison exhibited on October 20th, 1902, a specimen of gneiss from bed-rock taken at a depth of 50 feet at the corner of Broad and Exchange Streets, a second from 45 feet below the surface at 40 Exchange Place, and two others also taken at that depth at about the same spot.

He also showed specimens of serpentine from boulders found in the excavations for the Stock Exchange building on Broad Street between 40 and 60 feet below the surface.

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 Street, between Greenwich and Washington Streets, were 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.

Accumulations of sand in heavy and extended beds were encountered in Elm Street during the construction of the Rapid Transit Subway, beds which were continued northward through Lafayette Place, at Astor Place, through lower 4th Avenue, and up to Union Square. Rock ledges were penetrated beyond this point, revealing on the line, as at 23d Street, subsidences filled with sand, clay, and surficial fillings.

Again, on the track of the Subway beyond or north of 134th Street very deep hills of sand were entered, themselves partially separable by a color line.

Seldom in excavations of the size of that made for the new Wanamaker store has the nature of the soil proved so advantageous to the contractors. In the plot excavated, extending along the entire front on 4th Avenue and back on 8th and 9th Streets about 200 feet, not one stone has been encountered which was large enough to require a drill to dislodge it.

That the soil generally was of clay and sand was known before actual operations were begun, borings to a depth of 25 feet having been made over almost the whole area. Another feature, which has greatly facilitated the work, is the fact that at a depth of about 35 feet below the street level there is an almost solid layer of rock. As the depth of the foundation is to be 25 feet, it has been an easy matter to sink the 161 caissons necessary to support the fourteen-story building the remaining 10 feet to this solid rock.

It has been usual to regard this assortment of beds of sand, clay and gravel as entirely quaternary, or derived from drift. The actual confusion of material originating in the sub-aerial 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 quaternary 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 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 one 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 eighty 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 débris 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 land allowed the rapid currents of the two encircling rivers to attack the drift débris, 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 résumé of this article. The nature of the boulders found in this portion of the "drift" is mentioned in the accompanying paper on the "Evidences of Glacial Action," etc.

The increasing number of very high buildings ("sky-scrapers") in the lower districts of Manhattan Island has resulted in enlarged and more detailed acquaintance with the surface conditions above the floor rock, though the general expression and succession is identical, or but slightly varied throughout, at all the new basements. Some of these extend downward to considerable depths. In the Commercial Cable building (Broad and New Streets) the cellar floor is sixteen feet below the water-level, in the Mutual Life extension (Cedar Street) the cellar is thirty-two feet below the water-level. Messrs. Weiskopf & Stern, engineers of the City Investing building, furnished the following interesting statement:

"The soil under this building is a very fine sand mixed with very soft loam, and is almost of a uniform character from the top to hard pan. We encountered hard pan at a depth of about 65 feet below what we term 'curb A,' which is the curb level on Church Street, at the south side of the lot, and which curb is about 9 feet lower than the Broadway curb in front of this building. The mean low-water level is about —17 feet with reference to curb A, and the level of the boiler-room floor is 21 to 21 1-2 feet below curb A. The building is founded on hard pan, which varies in thickness from 0 to 18 to 20 feet. In such cases where the hard pan was very thick we put the concrete bed on this hard pan after removing about 4 feet of it. Of course, where we encountered rock without an overlying layer of hard pan we founded it on this rock." (Hard pan is here understood as a very consolidated mixture of clay and boulder rock.)

The foundations of the Hudson Terminal Building rest on the Manhattan schists or gneiss 85 to 110 feet below the street curb (J. V. Davies, C. E.), passing through, above the gneiss, 10 to 15 feet of "hard pan," above which were sand beds, mud, and filling. Manhattan schist was taken 390 feet below curb at Cortlandt and Church Streets (A. S. Coffin), and a flake of granite from granite vein at 240 feet below curb at Cortlandt and Broadway (A. S. Coffin).

General conditions respecting the foundations of buildings at the lower end of Manhattan Island have been described in the following language by Engineer T. Kennard Thomson:

"Under the New York quick-sand, which is from thirty to sixty feet thick, we find from two to thirty feet of hard pan. Sometimes this is directly on the rock, and sometimes we find masses of sand and boulders under the hard pan. Good hard pan, if on bedrock, will hold up any building that ever will be raised in New York, but nothing except personal examination of each individual caisson foundation on the job is sufficient to decide whether the hard pan is really good, and even then it is necessary to determine if the good hard pan extends to the rock or not. This opinion is the result of having been down in the air chamber more than two thousand times.

The deepest caisson foundation in New York is under the Mutual Life building, where the depth is one hundred feet below the curb and eighty-five feet below the surface water, through thirty feet of quick-sand, twenty-three feet of hard pan, and then thirty-two feet of sand, boulders and decomposed rock, which we took out with a shovel."

Fossil evidences as to age and past conditions of the Manhattan Island rocks are very rare, or unknown. The following interesting note of J. Howard Wilson, connected with excavations in Rector Street, is suggestive of a former boreal climate:

"In excavating for the new building for the United States Express Company, on Rector Street, between Sixth and Ninth Avenue elevated, Mr. Daniel E. Moran, C. E., found resting on the bedrock forty feet below the surface a small deposit of *Venus* shells, fragments of wood and some peaty matter. This deposit was covered by ten feet of glacial drift which, in turn, was buried under thirty feet of sand, probably of post-glacial age. The fossiliferous deposit was apparently protected from the ice action in this spot by a local ledge or shelf of the bedrock.

The *Venus* shells resemble very closely those of the recent *V. mercenaria* Linn., but differ from them somewhat and along a line which seemed to identify them with the variety *antiqua* of Verrill from the Pleistocene deposits of Sankaty Head, Nantucket. The Manhattan specimens were compared with a number of these in the collections at Columbia University, and the identification was found to be complete. The variety *antiqua* is an unusually massive and strongly sculptured variety."

This shell—a hard-shell clam or quahog—is regarded as symptomatic of cold currents, and has been found in shell beds on Nantucket Island, in which were unmistakably associated species of shells decidedly northern in habit.

Professor William H. Hobbs * has taken pains to investigate the underlying rock flooring of Greater New York, and has gathered together a great many records from the engineering work carried on in the construction of the East River bridges, the tunnels of the Pennsylvania R. R., the various municipal bridges connecting Long Island with New York, the Croton aqueduct, the Subway in Manhattan, the Harlem Ship Canal, together with the reports of borings, excavations,

*The Configuration of the Rock Floor of Greater New York, William Herbert Hobbs, Bulletin 270, United States Geological Survey.

foundations, wells, etc., and while his studies have be
cially influenced by his views on the formative causes
present outline of Manhattan Island (see Section on
ways, p. 110), his researches are interesting. They a
however, all previous impressions as to the rock basem
the city, as being gneissoid, schistose, and granitic, wi
ripheral beddings and interior fillings of sand, gravel and
and the presence of limestone areas north and, perhaps,
eastward. They have, however, also furnished sugge
and instructive outlines of the contour of the underlying r
and shown its irregularity, its folded, creased, and channe
surfaces. These results are referred to more at length un
Water-ways (p. 110) and the Evidences of Glaciation in a
About Greater New York (p. 190). The Section of the Ro
Basement of Manhattan along the line of Broadway from t
Battery to 33d Street, presented as Map I, is reproduced fr
Professor Hobbs' pamphlet.

TOPOGRAPHICAL RETROSPECT*

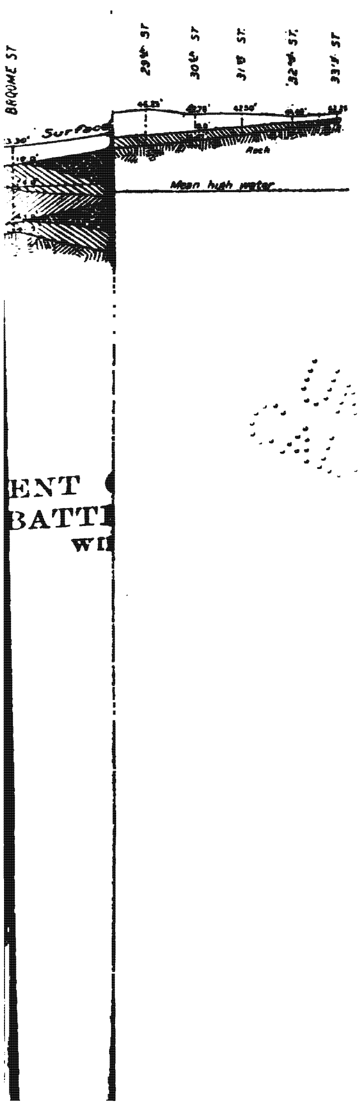
In the map of T. Maerfchalckm (1763) the Negro Burial Ground was around Collect Pond, just north of the Common (the present City Hall Park), on which stood the Poor House and Powder House, and by the side of which, as a prolongation of Nassau Street, the Highroad to Boston ran through Chatham Street to Chatham Square, and thence followed the Bowery.

The Battery was formerly an elevated section, and is referred to in early records as a bluff, the land between Trinity Church and the present Bowling Green being somewhat raised, fronting the Hudson as a receding bank.

Governor's Island, which was originally a perquisite of the Director-General, and formerly known as Nutten Island, was at an early day so extended towards Red Hook on Long

*For most of the material in this section I am indebted to the admirable and unique papers, letters, sketches, etc., of D. T. Valentine, in the Manual of the Common Council of New York.

MAP I


BROOME ST
29th ST
30th ST
31st ST
32nd ST
33rd ST
Surface
Rock
Mean high water

Island, and the channel was then so shallow that cattle passed to and fro across the latter.

An extract from John B. Jervis' "General Description of Line of the Croton Aqueduct," describing the topography of the Harlem River at High Bridge and the character of the river bottom, is not without interest. "The width of the river at the place where the aqueduct line crosses it is 620 feet at ordinary high-water mark. As has been before stated, the shore on the southern (Manhattan) side is a bold rock rising from the water's edge at an angle of about 30° to a height of 220 feet. On the northern (Bronx) side a strip of table-land forms the shore and extends back from the river 400 feet to the foot of a rocky hill, which rises at an angle of about 20° to a few feet above the level of the aqueduct. The table-land is elevated about 30 feet above the river; the channel of the river to which the water is reduced at very low ebb tides is 300 feet wide, and the greatest depth 16 feet. Each side of the channel the bed is a deep mud, covered from 3 to 4 feet at ordinary flood tide. Next below the mud there is a thin stratum of sand, and this is followed by a stratum of sand and large boulders or detached rock; there has been found in the coffer dams for two piers, Nos. 8 and 9, a compact marble rock (Inwood Dolomite), and in the coffers of Nos. 7 and 10 a stratum of clay and sand that is quite impervious to water and affords a good medium for piling."

Pearl Street has its circuitous and curved course because originally the street was the nearest to the river, and its direction was determined by the shore. It was a very thriving street, the business of that section of the city being the most unflagging and important because of the active traffic in farm products with Long Island. The edge of the East River was lower and less bold and "declivitous" than the shores of the Hudson, and the rear of the gardens of the buildings on it in those early days was washed by the river's tide. It was built up to Broad Street, which then was occupied by a creek. Pearl crossed it on a bridge. It led past Mrs. Van Clyff's farm, her residence being on a bluff near the present junction of John and Pearl Streets. Thence it passed Mr. Beekman's farm and orchard, near the street which now bears his name. Thence it crossed a neck of land between Beekman's Swamp and the river, about the present head of Peck Slip; thence it continued to the present site of Franklin Square. Here, in course of time, it became convenient to effect a junction with the high-road to Boston (now Chatham Street), and the only traversable way was along a ridge which then extended from the top of the hill at Franklin Square to the Boston road. Accordingly this was staked out and became a thoroughfare, naturally taking the name of the street from which it ran. Here it would have probably stopped its circuitous course, but it happened that opposite to its junction with the Boston road there came in a lane leading from Broadway also to the Boston road, past a powder house (then and for a long time standing upon a piece of ground almost insulated by the fresh-water pond—the Collect), the lane became known as Magazine Street, but finally, it being the natural continuation of Pearl Street, it was adopted as a part of that ancient thoroughfare (Valentine).

Maiden Lane passed originally as a sequestered valley, between hills and elevated slopes. Broad Street was so named because of the breadth given to it by its former occupancy by a wide marshy valley traversed by a small stream or drain. The sides of this drain were bordered by buildings, which were built far enough back from the stream to permit the construction of a roadway. So the street, when afterwards the drain was filled in, attained a somewhat unusual width. Beaver Street was formerly known as the "Beaver Canal," being a branch of the Broad Street stream. Broadway was itself below the City Hall Park, a natural ridge, with a superior width about the size of a convenient road. It led to the Pasture Lands and Commons of the present City Hall Park.

A little south of the present union of South William and

Beaver Streets was a mill, either wind or horse, and as the water-power was only to be obtained in positions exposed to the attacks of the savages, it was placed upon a hillside.

"A road led to this mill from Broad Street, and turning from the mill at right angles, it came out in a road, now Stone Street. The road from Broad Street to the mill was afterwards left open, and in course of time became known as Mill Lane, subsequently as Mill Street Lane, afterwards as Mill Street. In course of years the old mill was taken down, and in latter days the ancient mill lane has been extended through to William Street." This is the present South William Street.

Moore Street has an interesting history, and it is illuminative of the original physical condition of this region. The Customs House of New York was formerly on the north side of Pearl Street when Pearl was the water-front at this point. A pier was built out in front of the Customs House upon which goods were landed from small boats and vessels which could approach it. This pier was called the "Bridge" or "The Landing Place." Filling in of this section along the present Water Street ensued, the old pier became dry land, and its position being public property, was left as a street, and from having been the mooring place of boats it was so called, though the abbreviated cognomen of Moore was attached to it.

The temptation in this connection is irresistible to give Vallentine's account of the origin of Hanover Street and Slote Street, and as the use of this work amongst public school pupils is helpful, if such facts are recorded, in preserving their local pride, the disgression, I trust, will not be unduly censured:

"Previous to the year 1700 the whole space between William, Wall, and Pearl Streets was not crossed by any street. Soon after that date a slaughter house was built in the vacant space in the center of that block, about the present southwest corner of Beaver and Hanover Streets. To reach this a lane led nearly on the present line of Beaver Street from William

Street, and then turned at right angles for a way of egress into Pearl Street. The lane running into Pearl Street was on the present line of Hanover Street. The whole lane was then called Slaughter House Lane, subsequently shortened into Sloat Street Lane, afterwards Sloat Street."

Broadway carried the pedestrian to a high hill with more or less abrupt descents near the present City Hall Park, which was succeeded at Chatham Square by another commanding eminence, from which started the broad thoroughfare up the Bowery.

The Swamp is thus described in the records of the Secretary of State's office at Albany: "Said swamp is filled constantly with standing water, for which there is no natural vent, and being covered with bushes and small trees, is by the stagnation and rottenness of it become exceedingly dangerous and of fatal consequence to all the inhabitants of the north part of the city bordering the same, they being subject to very many diseases and distempers, which by all physicians and by long experience are imputed to these unwholesome vapors occasioned thereby, and, as the said swamp is upon a level with the waters of Hudson's and South Rivers, no person has ever yet attempted to clear the same."

We learn from an early record some soundings which are of real interest; they were taken in the harbor of the city: "Depth of water in harbor from Long Island to Staten Island, 4, 4, 4, 4½; 6, 11, 12, 13, 12, 9, 6, 6, 5, fathoms right under the shore of Staten Island; a second line three-quarters of a mile farther south where the river is narrowest (presumably the Narrows), 5, 6, 14, 15, under the shore, falling then off to 6, 2, 1½, with a bar on Long Island side."

Facts gleaned from Valentine's records about the islands in the harbor are also of considerable topographic and of historic interest: Ellis or Gibbet Island (now the site of the Emigrant Station) was formerly known as Oyster Island, and was famous for the abundance of good oysters to be obtained on its shores. It was at one time nicknamed Bucking Island.

Ward's Island was formerly known as Great Barn Island, given in 1637 by Heyseys and Numers, both Indian chiefs of "Mayrechkeniockingh," to Wouter Van Twiller; it was estimated to contain 200 acres, called by the Indians "Teukenas." After many vicissitudes of ownership it passed into the hands of the Ward family. This and Randall's Island adjoining were used by Thomas Delavall for grazing purposes, indicating their alluvial and fertile surfaces. Blackwell's Island was conveyed to Van Twiller at the same time as Ward's Island, and then was supposed to comprise 120 acres. It was called by the Indians Minnahanock. Governor's Island was known to the Indians under the name of Pagganck, and by the Dutch as Nuttens or Nut Island. It contained in 1756 about 120 acres.

Bedlow's Island was thus called from its earliest owner, and afterwards, while in the possession of Captain Archibald Kennedy (afterwards Earl of Cassilis), it became known as Kennedy's Island.

Randall's Island was first known as Little Barent's Island, afterwards contracted into Barne's or Barn Island, and patented to Thomas Delavall, then Collector of the Customs at New York. It came subsequently into the possession of James Carteret, then to Philip Pipon, and then to Elias Pipon in 1732, and used by him as a place of residence, because of its romantic beauty, known as *Belle Island.* It passed from him to St. George Talbot, who, charmed by its attractiveness, resided there in 1747. From Talbot it passed to John Montressor, Captain of Engineers in the British service, and stationed at New York. The succeeding owners were Ogden and Randall. Jonathan Randall worked its farming facilities so successfully that in ten years he paid the whole purchase money of £2,400. He resided there for fifty years. It passed from his family to the possession of the Corporation of New York.

Some transgression of the sea inland amongst the East River islands is obviously indicated in early maps, as in a chart of 1855 the shallow bottoms east of Randall's Island are designated as Sunken Meadows.

The presence of springs on Manhattan Island is well established, all due to surface pressure and the saturation of superficial beds of rocks or earth. The ancient source of pure water to the inhabitants of this city was one of the springs which fed the fresh-water pond known as the Calch-hoock, Kolch, or Collect, which marked the site now occupied by Centre Street. This Pond was surrounded by high hills, bordered by a marsh, and was popularly reported to have a depth of fabulous extent, though in reality its greatest depth did not exceed fifty feet. It was in its earliest fame celebrated for its fish, but when from protracted invasions by anglers these declined, it was positively emptied by a destructive assault with nets.

The Old Tea-Water Pump was erected over a spring situated in a glade or hollow near the present juncture of Chatham and Roosevelt Streets. We are told a brook crossed the road at that place, over which was a bridge which was doubtless of very sweet significance to the young people of the olden days, for the bridge was known as "Kissing Bridge," and the explanation of this sobriquet is given in this quaint narrative from a reporter of 1755, the Rev. Mr. Barnaby. He says: "The amusements are balls and sleighing parties in the winter, and in the summer going in parties upon the water and fishing, or making excursions into the country. There are several houses pleasantly situated up the East River, near New York, where it is common to have turtle feasts. These happen once or twice a week. Thirty or forty gentlemen and ladies meet and dine together, drink tea in the afternoon, fish and amuse themselves till evening, and then return home in Italian chaises (the fashionable carriage in this and most parts of America, Virginia excepted, where they chiefly make use of coaches, and these commonly drawn by six horses), a gentleman and lady in each chaise. Just before you enter the town there is a little bridge, commonly called the 'Kissing Bridge,' where it is customary, before passing beyond, to salute the lady who is your companion."

It seems insisted in early records that the wells of New York furnished a very indifferent water; its quality is described as "sickening," and even horses refused to drink it. Before pumps were in use, old-fashioned wells with pulleys and buckets were in common adoption, or the long sweep-pole. The first well was in front of the fort, and this for many years was the only public one in town. The second was in front of the City Hall, at Coenties Slip. In the year 1690 there were about a dozen public wells in the city standing in the middle of the street. They were given different names according to local circumstancs, as "De Riemer's Well," "Tunis De Kay's Well," etc. From Valentine's Manual of the Common Council, 1855, p. 556, this pleasing and useful description of the Old Tea-Water Pump is taken: "The first mention we have of the use of the spring water from the site of the Tea-Water Pump is found in the diary of a traveller in New York, in 1748. He says, 'There is no good water in the town itself, but at a little distance there is a large spring of good water, which the inhabitants take for their tea and for the uses of the kitchen. Those, however, who are less delicate on this point make use of the wells in town, though it be very bad.'

"Shortly before the Revolution this spring and its vicinity were made into a fashionable place of resort at which to procure beverages adultered with pure water.

"A pump was erected over the famous spring, ornamented grounds were laid out around it, and the Tea-Water Pump Garden held forth its attractions under the most seductive influences. But its ancient glories have long since departed, and it is now almost a thing of tradition. A gentleman about ten years since commenced a search for this relic of ancient festivity, and says he found the once celebrated Tea-Water

Pump, long covered up and disused, again in use, but unknown, in the liquor store of a Mr. Fagan, 126 Chatham Street."

A dry well with free stone wall sunk in the sand was uncovered in digging the present subway at Astor Place and 4th Avenue. It was completely dry.

In the reminiscences of David Grim we learn that at Augusta Street there was a valley between Windmill Hill and Pot-Baker's Hill, about the center of Augusta Street, and midway of Pearl and Parly Streets.

The various inlets or small harbors known as slips, so prevalent on the East River side of the city, are thus designated and described by David Grim:

> Whitehall Slip took its name from Colonel Moore's large white house. The house was adjoining to this slip, and was usually called the White Hall.
>
> The next was Coen and Anty's Slip (Conrad and Jane), called so after Conrad Ten Eyck and Jane, his wife; they lived at the corner of Little Dock Street and that slip.
>
> The next was called the Old Slip, being the first in the city.
>
> The other was called Burling Slip, after the name of a Mr. Burling, a respectable family living at the corner of Smith's Flie (nów Pearl Street) and Golden Hill.
>
> The next was called Beekman's Slip, so named after a family living at the southwest corner of Pearl Street and said slip.
>
> The next and last on the East River was called Peck Slip, after the name of Mr. Peck, who was proprietor of the land on the side of said slip.
>
> There was only one slip on the North River side, that at the foot of Oswego, now Liberty Street.

Cherry Street, which took its name from running through or to a cherry orchard, is one of the old streets of New York, and the contrasted topography about it in old days is gleaned from chance relations, deeds, records, etc., which show "that the heirs of Govert Loockerman sold at auction a lot on this island at the ferry formerly belonging to Egbert Van Borsum, also a parcel of meadow with a slip of upland abutting thereto with the south side on lots of Henry Bresier, with the northeast side on the Ould Kill, with the southeast side upon the highway along the East River, and with the northwest side upon the highway, amounting to about seven acres."

Streams or brooks widening into tideways entered East River north of Central Park, some heading back almost as far as Manhattanville (130th Street). The shore on the East River east of Mt. St. Vincent appeared to be extensively dissected by creeks and muddy estuaries.

City Hall Park, formerly known as the "Vlachte" or "Flats," "Second Plains," "Commons," "Fields," was originally a grazing place of the cattle belonging to the citizens of New Amsterdam. It is interesting to read the surmise of early writers that the Indian tribe of the Manhattans may have been centered at almost this exact spot, in some sort of a village, as a mixture of shells with the upland soil has been here discovered. To this reservation in a more civilized era repaired the cows of the burghers, carefully tended by a cowherd, "whose business was for a certain stipend from each family to perambulate the village of New Amsterdam, and blow upon his horn a note of invitation at the garden gates of the inhabitants, whose cows being let out, joined the common drove, and were driven through the romantic valley road now called Maiden Lane, and having arrived at the common pasture were restrained from more distant perambulations by the watchful herdsman."

In a record of 1797 of the necessary change of grade in Broadway, by which the approach of that thoroughfare to the bridge across the canal or drain at Canal Street was made more gradual, it is discovered that at Magazine Street (now north end of Pearl Street) a depth of four feet nine inches was removed from the natural elevation of the soil, at Leonard Street, fifteen feet six inches; the ground rising from this point, it was found necessary at about 525 feet above Leonard to cut down through 22 feet 10 inches. "This was the highest point, and thence the natural hill descended somewhat steeply to the meadow." The arched bridge at Canal Street was ten feet seven inches above the meadow.

In 1805 the Collect Pond was inspected and provisions begun for filling it up. It had become a nuisance, a menace to public health, on account of the dead animals put in it.

The Collect Pond in Centre Street was part of a transverse depression entering Manhattan Island from the North River, and inundated and partially navigable. In the region of Canal and Lispenard there was a marsh covering a surface of seventy acres, covered with stunted bushes, filled with swamp rubbish, and the "rotten growth of ages." It became a serious annoyance to health. Fever and ague were so prevalent in its neighborhood that farmers could not keep their laborers. Cattle straying into it were entombed in its muddy recesses. In 1732, Mr. Anthony Rogers was permitted to receive it in fee-simple on condition of draining it, and paying a moderate quit-rent. The bushes were cut off and a large drain was cut through the center of the swamp, taking its waters into the North River. The effect of Rogers' drain seems to have been too complete. The Collect Pond was partially depleted, leading, in 1734, to a summary action in law on the part of farmers and others on its borders, and resulting in the filling up of thirty feet of the drain at the "Fresh Water Pond," so as to prevent the exhaustion of that (then) useful body of water. Leonard Lispenard, of French descent, was the owner of the farm and brewery near the edge of the swamp. North of the swamp was a public garden and resort known as Brannon's Gardens, from which the street of that name secured its name.

The irregularities of the original surface of Manhattan Island may be easily imagined from the pleasant and picturesque features of its old windmills so thoughtfully given to us by that princely commentator and scribe, D. T. Valentine. These windmills naturally occupied commanding positions, the summits of hills, ridges, etc. There was one in 1656 adjoining the fort standing upon the present State Street, another was on the eminence north of Wall Street, owned by Jan Vinje, "farmer, brewer, and miller." It is impossible to resist the wish to repeat the genial restoration presented by Valentine: "A curious sight it must have been to see the farmers' wagons laden with grain traversing the shore along the East River, winding up the romantic valley now called Maiden Lane, and depositing their loads at this edifice, then standing in the midst of a clearing of forest trees of mature growth. The snug little stone farm house, with its loophole windows to keep out marauding savages, the low doorway with its bull's-eye windows in the panels, the motley assemblage of domestic animals, and slaves of all sorts and sizes, which then formed the great part of a domestic establishment, the waving grain of the adjoining field, the newly planted orchard, all formed a picture which can hardly now be idealized in connection with that ancient and long populated part of the city. Another was farther eastward at the ferry, another upon the south part of the present park, then a desert spot, covered by stunted bushes and hoop-pole saplings and offering no annoyance of forest trees to the free course of the winds above the underwood."

There was another windmill on the North River shore below St. Paul Church to attract Jersey farmers, "those venturesome men who had penetrated the wilderness and planted the fertile region of Hackgingsach, and those, too, along the Jersey shore, in sections called by the Indians Ahasimus, Hobokenhacking, and Carno cuipa."

The east side of the city, south of Chatham Street, was depressed and valley-like, and was originally known as the Vly or Valley, from whence old Fly Market at Front Street and Maiden Lane originated.

The village of Greenwich lay beyond the Lispenard meadows, and offered a diversified surface covered with farms, woods, orchards, and nurseries. There was Richmond, Colonel Burr's place, where Charlton Street is now, and then covered with cedar woods. From Greenwich village the people in winter resorted to the overflowing Collect and Lispenard meadows, the marshy land of the latter extending then down Chapel Street quite to Thomas. In winter these meadows were a great skating pond for the public.

A verbal sketch of extreme interest, prepared by Valentine, exacts an attentive perusal. It was written in 1857. "The superficies of the lower as well as other portions of the island was originally graceful, varied, romantic and prepossessing, diversified in all the forms of hill and dale and valley, of brook and rivulet, and winding stream of limpid water, which made up numerous views and prospects most captivating. The higher line of lands was from the Battery along where now is Broadway (a bluffy height south of Trinity Church, then commanded an extensive prospect) far on to the north, in varied degrees of elevation. But like a backbone, in the center it was uniformly highest, and fell off gracefully to the east and west, except where the brook crossed it; where it fell to a valley from the south and north—the Collect of freshpond being on the east and Lispenard Meadows being on the west, in both of which were large springs, which kept the water fresh and flowing. The water was very deep at where now is the corner of Grand and Greene Streets. About 1809 or 1810 a gentleman named White was there drowned by walking there by mistake at night.

"At the corner of Grand Street and Broadway was a high hill, from which the land gracefully fell off toward the brook at Canal Street, and up which Broadway or the King's Bridge road was. From that hill was a view which in majestic loveliness was very captivating. Below in the valley, on each side the road, the waters were seen flowing toward each river, those on the east side finding their way through and over the lowlands where now is Roosevelt Street, and those on the west finding their way through the lowlands of the meadows of Lispenard to the North River through a sewer made through a dike, where now is Greenwich Street, and the ponds on each side varying in width, and each presenting a beautiful sheet of water, the lowlands of Lispenard extending by a branch down what is now Chapel Street as far as Thomas Street. To the south and west was a succession of hills which were overlooked, and on one, to the west of and near Broadway, a little above Anthony Street, was once Curry's ice-cream garden; from thence to the west beyond a valley which intervened, and where now is Laight Street, near St. John's Park, was the high hill on which was the country seat of Leonard Lispenard. To the west the eye rested on the green woods and lands of Richmond Hill, a romantic spot, where once resided Colonel Burr, and in the intermediate glen was the residence of Mr. Glover. To the south lay Broadway, then a highway road, the hospital recently erected beside it; and near and below the hospital was once the mead garden of an old lady named Elsley; the rise of property to her posterity realized a fortune. Below these, on the east side of Broadway, where now is Mr. Stewart's large store (Chambers Street) were the lands once known as the Negro Burying Ground. All this region and the King's farm and the lands of King's College, in Robinson Street, and the Fields, now the park, were seen at a glance from that high hill at the corner of Grand Street. On the east lay the broad lands of Stuyvesant and Kipp and their domiciles, and that beautiful sheet of water, Kipp's Bay, and near at hand were the lands that since formed the east and west Boyard Farm; and far, far away, and yet before the eye, were the North and East Rivers and the magnificent bay and the lands and shores beyond. It was indeed in its own nature and condition an island of magnificent scenery. The house on that top-hill was built downward as the hill from time to time was depressed, until it became a three-storied building. It was finally removed. Near it was a higher hill, called Bunker's Hill, from whence the view was also grand.

"From the latter hill might be seen also Judge Benson's country site, where now is Bleecker, near Carmine Street; the house is still standing (1857). His place bounded on the

Minetta Brook, a stream that flowed from above and through a part of Potter's Field, now Washington's Square, passed down by Judge Benson's place and separated it from Sand Field, called Sandy Hill, and thence passed westerly by the north of Richmond Hill, opposite to which it expanded into a large pond; then at where now is Varick Street it contracted into a narrow brook, from which it fell off to a salt meadow and found its way to the North River. Greenwich was separated by this brook from the city. The scenery here was beautiful. From the top of Richmond Hill an enticing prospect was presented. On the south the woods and dells and winding road from the lands of Lispenard, through the valley where was Borrowson's, and on the north and west the plains of Greenwich Village made up a rich picture to gaze on."

There was a well at the fort in Bowling Green which, according to tradition, supplied the citizens of the infant colony, as well as the garrison of the fort, and whose surplus waters found their way into a little brook on the present line of Beaver Street, and aided in extending or preserving the marshy section in Broad Street, then called Blommaert's Valley. Near the well a hillside ran down to the water at the present Battery, and this contour justly permits the inference that the well was supplied from the immediate water-shed.

Amongst the ancient waterways and springs the reverent chronicles of old conditions finds that a rivulet hidden in foliage came tumbling down the rocks on the present line of Gold Street, fed by a never-failing spring on the south side of John Street, near Gold.

We are told in "Recollections of an Old Citizen" that in 1795, on both sides of Broadway as far as the eye could reach north, hills full fifty feet high occupied the ground. It was then a common country road, unpaved and walled in by high clay banks crossing Canal Street by a stone bridge.

The present Chatham Street formed the descent of the high hill known as Catimuts Hill (probably an Indian name) to the Fresh Water brook that ran from Collect Pond to the East River, and this hillside was so steep that in order to avoid the abrupt declivity another road of easier grade was formed "diverging from the main road (the Bowery Boston road) eastward, about on the present line of Duane and Rose Streets to the junction with Pearl Street."

Old Harlem Creek once wound its tortuous way through Harlem, when that populous section was thinly settled and an outlying village of New York. The creek flowed out of Goldfish Pond, which occupied a basin between Lenox and 7th Avenues and 117th and 119th Streets. At 110th Street it crossed the fields to 5th Avenue, and poured into the Harlem Meer, filling a bowl at 110th Street, which is now a portion of Central Park.

McGowan's Creek was also in this neighborhood, flowing apparently in 106th Street across to 5th Avenue, and formerly (fifty or sixty years ago) crossed by a bridge at 3d Avenue and 106th Street.

The threaded and inundated character of the old shores, now filled in and occupied with bulk-heads, is shown by this extract from Dr. John Flavel Mines (Felix Oldboy): "Manhattan Island was the name given to a high knoll of ground on the East River, above the foot of Rivington Street, containing about an acre of land, surrounded by creeks and salt-marsh, and at high tide partly covered with sea-water. . . . Just north of Manhattan Island a natural creek ran up through the center of the present Tompkins Square to the vicinity of 1st Avenue." Here was Burnt Mill Point, to reach which several creeks were crossed on small wooden bridges, and the bridges themselves "were attainable only after a decidedly moist tramp through soggy meadows and salt-marshes."

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 Street, 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 leveled 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 its appearance in any broad exposure, will be struck at once by the lined or banded structure. It presents 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, Hornblende 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, *viz.*, quartz, mica and feldspar. Besides these changes in nature it alternates in places with hornblende-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 fragments 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 gniess, the soft micas, the harder feldspar, and the very hard quartz.

It is to be observed that the gneiss is regarded here as including rock varieties which Professor 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 Street; at the entrance to the Park from 8th Avenue at 106th Street; along the bluffs at 110th Street 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 Street it was often seen to a great advantage, its almost vertical sheets cleaving off in huge plates being admirably shown. Sites also in West 93d Street, West 123d Street, and between 5th and 4th Avenues at 120th Street, 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 Street, 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, formerly 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 nor mica-schist displays its 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.

Professor 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 10th Avenue and the foot (east) of 50th Street. The very micaceous gneiss which, in some nomenclature, passes for mica-schist can be seen at a number of exposures on the east side, beginning at the East River Park, 86th Street 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 drift trap boulders; at 77th and 75th Streets and the river; at 73d Street in a moderately high bluff, east of Avenue A, and rather more micaceous, with fewer granite veins. It can be easily followed to 70th Street, and rises on either side of the Avenue, forming at 59th to 58th Streets and at 51st and 50th Streets, 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.

DIVISIONS OF THE GNEISS

Dr. Frederick J. H. Merrill, State Geologist of New York, has separated the gneiss areas in and north of Manhattan Island into three broad divisions, which are made referable to stratigraphical and lithological distinctions; that is, the divisions are due to a difference in age and origin. These distinctions have been worked out by their author with such skill and learning that no complete understanding of New York's local geology can be acquired without their mention, though in all respects they do not yet seem established.

These divisions of the gneiss areas embrace, first, the Fordham gneiss, so named from the place where it is prominently developed. Near Fordham it is a gray, narrow-banded and rather dense gneiss, at times very quartzose and again plentifully leaved with biotite mica, and containing the feldspars microcline, orthoclase and oligoclase. Amongst accessory minerals Merrill notices zircon, apatite, titanite, and magnetite; garnet, and occasionally constituent hornblende.

This Fordham gneiss stretches from Yonkers southward to Spuyten Duyvil, and forms the ridges west of the Bronx. South of Spuyten Duyvil it disappears on Manhattan Island, presumably pitching under the higher, more loosely constructed mica-schists. It appears, however, south of Fordham on Manhattan Island in the hill (now rapidly disappearing) which borders 7th Avenue at 155th Street. An eastern fork "disappears beneath the dolomite in Morrisania, but reappears near the Bronx Kills in Mott Haven, where it forms a low, anticlinal ridge interrupted by the kills. It was represented on Manhattan Island by a few outcrops below high-water mark at the foot of East 122d Street, which are now removed. Some narrow anticlinal ridges of Fordham gneiss are seen on the islands in the East River, notably Blackwell's, Ward's, North Brother, and South Brother, and it is the only laminated crystalline rock at present exposed on Long Island. There it may be seen near the court house in Long Island City and also along the shore of the East River from Ravenswood to Lawrence Point. It is also found in deep well borings on northwestern Long Island, where it is the subterrane."

The second division of the gneiss areas embraces the Manhattan (or Hudson) schist or the gneissoid and schistose rocks forming the surface and underlying the surficial drift of New York Island (Manhattan Island), and seen at Port Morris and on Randall's and Ward's Islands also. Merrill says: "The Hudson schist is more persistently micaceous, while the Fordham gneiss is more quartzose and more uniformly bounded. The foliation of the Hudson is also usually more crumpled than that of the Fordham." This is obviously true, as an observer can determine, but regions of the Manhattan schist conform (as Merrill admits) very closely to the Fordham rock in physical appearance. Merrill separates, as is pointed out later, these two contrasted beds into chronologically widely removed geological ages. (See p. 89.)

The third division of the gneiss embraces the Yonkers gneiss, not visible on New York Island nor seen within the limits of the greater city. It is typically developed at Yonkers and is a hard and quartzitic rock, with biotite (mica), hornblende, garnet, zircon, titanite, and apatite. The rock is foliated. Merrill regards it as an intrusive rock, that is, igneous in its origin, or more simply a softened or pasty lava-like flow, which has entered extensively the Fordham gneiss with which it is associated.

A rock also associated with the Fordham gneiss is the Lowerre Quartzite which appears at Lowerre, Bronxville, and Morris Heights, and which may have considerable significance. It is called the Poughquag Quartzite by Merrill. It is a hard, very siliceous rock, thin bedded in most of its exposures, white to brown in color. Dr. Merrill considers this rock the analogue of a Cambrian Sandstone, and regards it as the base of the sedimentary metamorphosed series of rocks on Manhattan Island. Overlying it is the Inwood Limestone (Stockbridge Dolomite), and underlying it is the Fordham gneiss, which the same authority regards as pre-Cambrian or Archæan (see page 89). These distinctions and the geological sequence of the New York Island rocks are reviewed in another section.

The universal presence of gneiss (or mica-schist) over Manhattan Island, its great depth, and the varying nature of its contents have been clearly demonstrated in the excavations made for the Rapid Transit Subway. The broad slabs of shining micaceous schist exposed in the pits at 42d Street and 4th Avenue and Broadway were very instructive, and their position, in vertical sheets, showing the steep dip of the bedded rock equally so. (Fig. 4.)

The very micaceous rock, which might not be considered as quite typical, from West 125th Street, near Riverside Drive, has been called by Dr. Julien a "schistose biotite-gneiss," and was described by Professor J. P. Iddings as having a structure "caused by flakes of mica grouped in lines curving about larger crystals of feldspar and quartz. It was made up of biotite, quartz, and feldspar, all allotriomorphic (which means crystallization in coarse-grained rocks where the component mineral crystals have irregular forms imposed upon them by adjacent minerals), with a small amount of muscovite, apatite, and zircon. The quartz grains are irregular, but the smaller are often rounded. The feldspar is chiefly oligoclase, with a little orthoclase."

Dr. A. A. Julien, examining a specimen of almost identical rock at 118th Street, found under the microscope that it was composed of "closely fitting grains of colorless quartz and feldspar." These two minerals formed about 65 per cent. of the whole volume of the rock, and of these the quartz made up 40 per cent., being angular and clear, inclosing a few bits, scales, of hematite, biotite, brown zircon, needles of fibrolite and minute fluid cavities. The feldspar displays polysynthetic twinning. Biotite mica (magnesian mica) occurs to the amount of 18 per cent., in reddish-brown plates. Muscovite mica (potash mica) makes up about 7 per cent., and is often or usually inclosed in the biotite. He found also sillimanite, and fibrolite (almost identical minerals), garnet, zircon, and hematite. These latter are in minute quantities imbedded and mingled in the interstices and in the substance of the quartz and mica.

Class Direction.—The teacher in crushing a piece of the mica-schist or gneiss will frequently be able under a glass to separate out some of these accessory minerals, or at least, under a glass, show their presence.

In such gneisses or schists, as illustrating their characteristic structures, the surfaces of cleavage (schistosity) are well marked, by having the longer axes of the grains of quartz and feldspar, parallel, as also those of the mica and other minerals.

In passing (and it will be further dwelt upon) it may be remarked that areas of the gneiss at various points over the island (Manhattan schist, etc.) have been hardened and apparently converted into more granitic-like masses by an injection of mineralizing material whereby quartz lenses, and stringers of granite (pegmatite) have been intercalated, and even perhaps a previous gneissoid mass changed into a granite. This process, called pegmatization, may have been in part a phase of refusion of the gneiss itself or the result of the injection of mineral menstrua through the foliation of the mica rock.

Dr. K. A. Lossen has, indeed, said (Einige Fragen zur Lösung des Problems der krystallinischen Schiefer, etc.): "It is not inconceivable that the pegmatitic aggregates represent, so to speak, the quintessence of the gneiss, exuded into primary cracks."

The schists (mica-schist or the gneiss) of Manhattan Island vary extremely in texture within a few feet. It is quite characteristic for the schist to become densely stony or feldspathic-siliceous in texture, fine grained and compact, brown to gray in color, and this in contact with strips of very micaceous schist, which at a short distance again show weathered surfaces roughened with projecting garnet crystals. Finely individualized garnet masses are also enclosed in the schists. Such alterations of structure are frequent in the exposed ridges of the Ramble in Central Park. The gneiss loses its prevalent appearance in places and becomes a granite-gneiss, wherein the stratified or laminated texture changes to an even mixture of constituents, and resembles a fine-grained granite. It is instructive to note the weathering and removal of the gneiss along the faces of its bedding or stratification. Softer films are destroyed and the harder stand in relief, giving a moulding-like effect. The gneiss displays jointage, broad faces of it being divided by cracks and rifts into rhomboidal blocks. This can be seen conveniently in the hillock of gneiss bordering the path leading out from the cave in the Central Park Ramble.

In this connexion the so-called Poughquag quartzite, although a gneissic sandstone, but containing mica; and affording a somewhat schistose structure, may be mentioned. It is characteristically developed with the Yonkers gneiss, and can be seen in Lowerre in typical condition. It is, however, found within the limits of the city, at Morris Docks on the Harlem River. (Fig. 5.) It is referred by F. I. H. Merrill to the Potsdam sandstone, and therefore represents the Cambrian formation. (See p. 4.) Where originally described at Yonkers it is white, at the Morris Dock exposure it is seen to be gray to brown gneissic in structure, indeed, a fine-grained sandstone, very compact, becoming a quartzite; the schistose portions are lined in parallel position by black specks of hornblende and by mica scales, much of the rock feldspathic and glistening with mica. Recently the Lowerre Sandstone and the Poughquag Quartzite have been separated. (Berkey.)

A great deal of stress has lately been laid upon the possible significance of the *biotitic* schists of the Manhattan series by those inclined to give a marked expression of vulcanism to the latter's origin, history, and modifications. The larger part of the mica in the Manhattan rock is muscovite, but there are well-developed occurrences of biotite in force, which Julien refers to as " sheets of glistening black biotite schist or biotitic gneiss, often garnetiferous." Biotite is a mica pre-eminently associated, or rather constitutionally involved, in volcanic rocks (it is an orthosilicate of potassium, aluminum, iron, and magnesium), and, as Rosenbusch tells us, is " in the eruptive rocks one of the oldest secretions, being formed immediately after the ores, zircons, and apatites, which minerals are frequently included in the biotite." On Manhattan Island much of its development is assigned by Dr. Julien to an alteration of hornblende during shearing, the hornblende itself representing a diorite (igneous) intrusive rock. This alteration forms "a purely biotitic gneiss or schist, or spangled or mottled micaceous gneiss, carrying both black and white micas. The latter differs from the prevailing gneiss of the Manhattan series, generally in a somewhat finer texture, greater richness in micas, and retention of many scales of both micas, which are long and bladed like those of the antecedent hornblende. Excellent examples were found at East 64th Street, on the East River; West 85th Street, just east of 10th Avenue; East 99th and 100th Streets, between Lexington and 4th Avenues; West 108th Street and Riverside Avenue; West 127th Street, near St. Nicholas Avenue; West 165th Street, on path above and Speedway; West 190th Street and Amsterdam Avenue.

"Through its great plasticity this biotitic or micaceous gneiss often bends about and incloses the bunches of less altered hornblende gneiss in a manner somewhat resembling a flow structure. Prominent localities were noted at West 90th Street, between 11th and 12th Avenues; West 92d Street, near the Hudson River; West 141st Street and 7th Avenue. At West 58th Street, between 9th and 10th Avenues, a group occurred of four thin layers of slaty hornblende gneiss and one of black biotite gneiss, separated by layers of micaceous gneiss. At 57th Street, only 200 feet farther south along the strike, this entire group was represented by a single thick bed of black biotitic gneiss."

By anyone accustomed to refer the hornblende intercalations to the metamorphosis of ferro-magnesian sediments it would seem entirely reasonable that contiguous (in this case over and underlying) beds would also contain iron and magnesia, mineralized, when the iron was low and the magnesia high, into biotite.

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 Street northward to 55th Street, 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 Street and 11th Avenue projecting from the south side of the street, a few feet west of 11th Avenue.

The granite is 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 10th 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 inclosing 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 inclosures 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, chrysoberyl, 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 inclosing 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, approximately conformable with the mica rock on either side, is most conspicuous at 106th Street and 8th Avenue 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 Street is a very fine-grained form, and Mr. Gilman Stanton has observed that from at least 87th Street to 95th Street 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 components, slabs of orthoclase being taken out more than a foot in diameter. One of the narrow veins in 110th Street 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 are 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 with the gneiss 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 is 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 Street, between the Boulevard and Riverside Drive, transverse to the foliated gneiss, appearing as 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. 6 and 7) can yet be descried sharply angulated or bent at one side.

Another vein was formely visible running vertically up a face of gneiss at the entrance of the grounds of the Convent of the Sacred Heart from 126th Street, 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 Fort George. The mica leaves

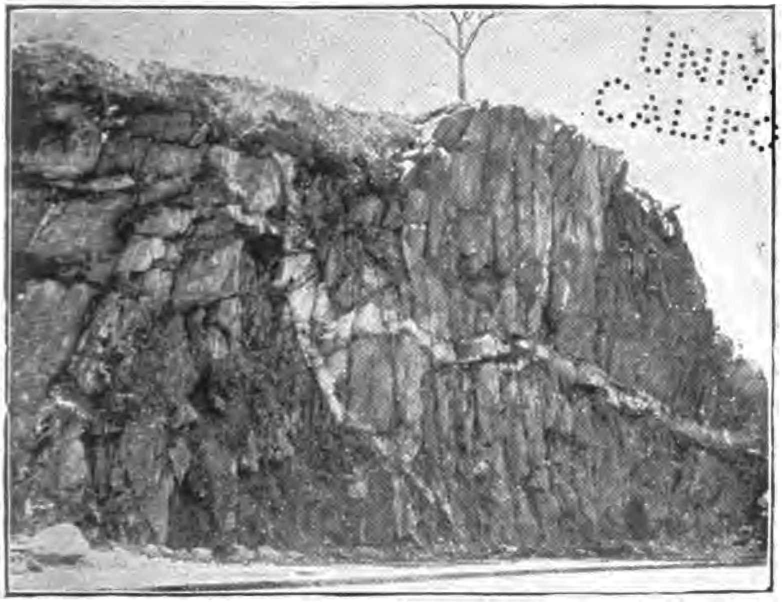


Fig. 6. Riverside Drive and 93d Street, south side, showing granite vein crossing gneiss beds.

Fig. 7. Riverside Drive and 93d Street, north side, in process of removal, showing granite vein crossing quartzose gneiss.

Fig. 10. Large garnet from vein in West 35th Street, half diameter.

Fig. 11. Entrance to Central Park at 106th Street, showing decomposing granite vein in schist.

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, are shown in the ad-

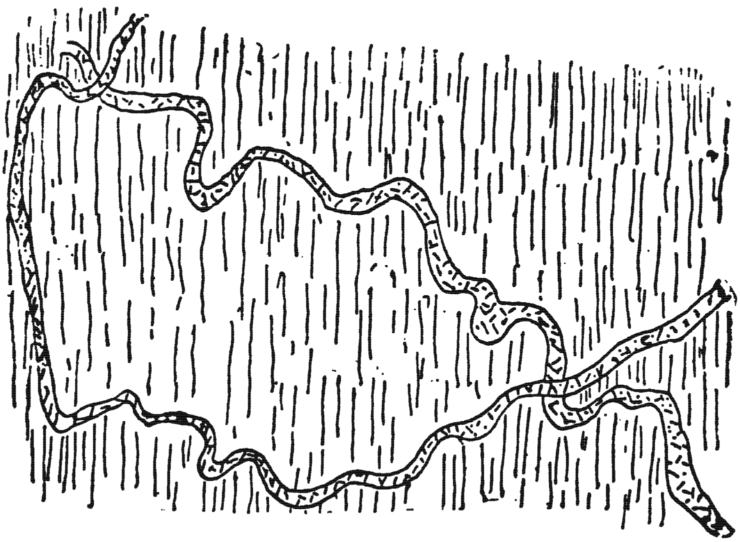


Fig. 8. Granite veins, 77th Street and Tenth Avenue.

joining figures, taken from sections now removed, west of Amsterdam Avenue, at 78th Street (Figs. 8 and 9).

Striking developments of granite venation (probably dike-like in origin) can be seen in the rock bluff at the head of 130th Street and St. Nicholas Avenue.

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 striæ 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. Gilman Stanton in 1888 at 62d Street and the Boulevard, those found by Mr. Niven on Washington Heights, and the large garnet (Fig. 10) now belonging to Mr. George F. Kunz, extracted from a vein in West 35th Street.

Tourmalines are taken out from the quartz of the granite and, as described in the section on the minerals of the island,

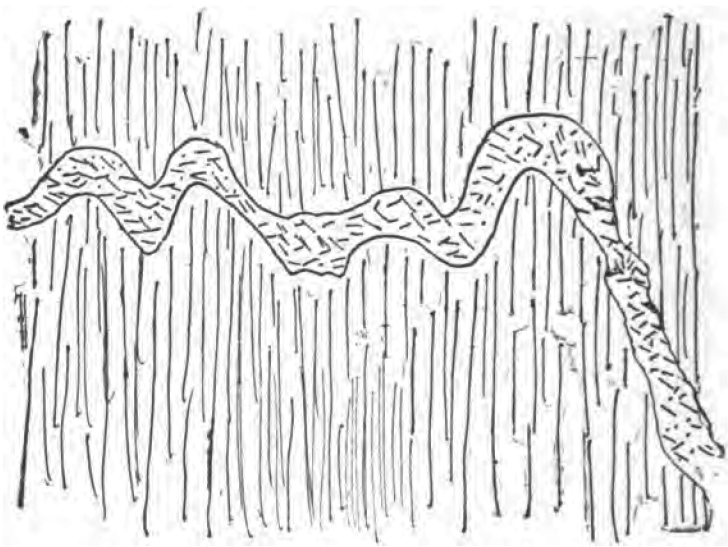


Fig. 9. Granite vein, 1-3 feet wide, 78th Street, between Tenth and Ninth Avenues.

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.

The weathering and decay of the granite are 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 Street, in the face of rock on 8th Avenue (Fig. 11) 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 4th Avenue and 77th Street, also at 43d Street and 1st Avenue. Also found at 56 feet below surface at 14 West 32d Street. (A. S. Coffin.)

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

Granite beds or sheets, coarse, pegmatitic, are found along a section on 58th and 59th Streets from 9th to 10th Avenues.

In the Pennsylvania Railroad excavation (Figs. 12 and 13) from 32d to 33d Streets, between 7th and 9th Avenues, with an extension towards 6th Avenue and another westward from 9th to 10th Avenue, granite was plentifully uncovered, appearing as a coarse rock (pegmatitic) on 32d Street towards 7th Avenue, and much softened and decomposed, abundantly in veins in the crumpled and folded gneiss between 7th and 8th Avenues on 32d Street, developed into a hill (from the level of the excavation) under 8th Avenue, and somewhat fine-grained, and extended west of 8th Avenue towards 9th on 33d Street, and again seen on 9th Avenue and 32d Street.

In the excavations of the Pennsylvania Railroad terminal, west of 9th Avenue, the granite inclusions seemed less relevant and simple, more confused, sporadic and involved, though the straight granite walls between the schists were not absent. About fifty feet east of 10th Avenue on the south side of the pit there appeared a broad sigmoid of twisted granite (fine-grained) vein, and the rock about was much crumpled, filled with strips and lenses of granitic material, rolled up and contorted, with their continuity severed or ruptured by squeezing. The material of some veins resembled a granite gneiss. Again, faces of the rock on the same side (south), and some four hundred feet east of 10th Avenue, were streaming with small veins, with two rolled masses of granitic matter, like big kernels, towards the upper edge of the cliff, suggesting included ponds of granite which have been elevated and compressed, sharing all the vicissitudes of the inclosing schist. There were, on north and south exposures in this part of the excavation, erect granite sections eight to ten feet wide, conformable with the schist walls and disappearing into these by a network of invading and parallel veinlets. In the so-called pegmatized areas quartz inclusions and fine-ruled lines of quartz and feldspar appear; in fact, an impregnation of articulating and scattered granitic or quartzitic threads, stringers and nuts. Figs. 12 and 13 show the quarrying out, with granite inclusions, of the gneiss or schistose rocks west of 9th Avenue in the Pennsylvania Terminal.

It seems apparent that the granite flows have, generally, at least, entered the schists before the latter's elevation, and that the complex represents a simultaneous catastrophe; but here, as elsewhere, there is suggested a refusion and recrystallization of the schists where the mariolitic-like pegmatization diversifies the schist with blebs, blotches, and shreds of quartz and feldspathic lenticles. It would be interesting to be able to follow these granite dikes deeply to their possible sources. As they were probably, at least many of them, intruded when the rocks were more horizontal, their ultimate termination might be in a communal granitic stock, of which they are the distributed and spreading tentacles. The reader will distinguish between the granite dike-like walls and veins and the pegmatization of the gneiss, where the latter incloses and is thickly mixed with granitic fragments, specks, and strings.

Dr. A. A. Julien in discussing the pegmatization of the gneiss has suggested a descriptive term, "occlusion," to represent the saturation of and the absorption and inclusion by the gneiss of the granitic or granito-mineralizing menstrua, which in some way, he states, has poured forth into the pores, laminations, and substance itself of the gneiss. His language,

Fig. 12. Pennsylvania Railroad excavation, 33d Street, west of Ninth Avenue.

Fig. 13. Pennsylvania Railroad excavation, 32d Street, west of Ninth Avenue.

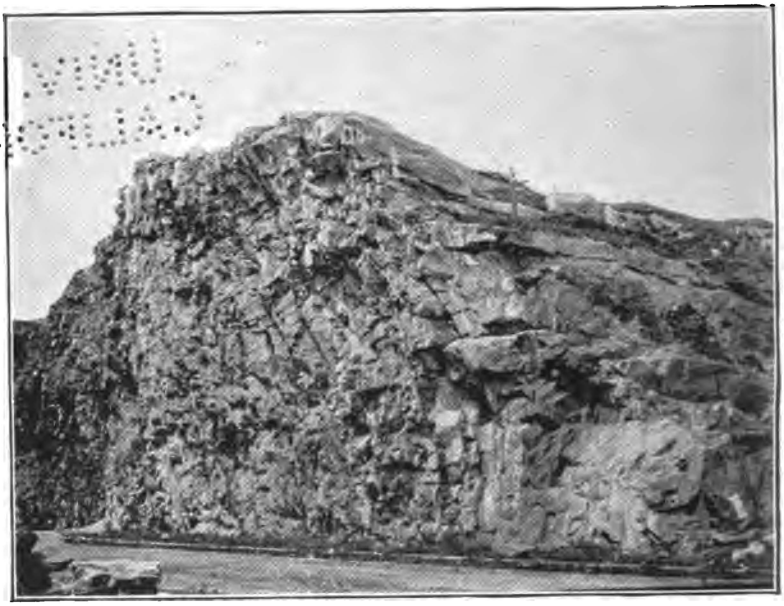


Fig. 14. North side of 152d Street, between Seventh and Eighth Avenues. Showing east dip, and contorted and deformed strata.

Fig. 15. South side of 152d Street. Close study of rocks, showing east dip and bedding.

with reference to localities also, is as follows: "Portions of the schists or gneisses themselves are sometimes found to have become separated and inclosed within the margins of intrusive pegmatitic dikes, perhaps displaying initial stages of absorption; for example, on the knoll in Riverside Park, opposite 83d Street.

"Much more important have been the results of interchange, in reverse order, from igneous intrusions cut loose during diastrophic movements from connexion with their underlying magmatic sources, swallowed up and permanently imprisoned within the invaded schists and these now found in various stages of shearing, alteration, and absorption.

"Examples of the acid occlusions have been described. The amount of pegmatitic and quartzose matter thus introduced has been so great that huge masses of saturated gneisses have been converted, in part or wholly, into bedded granite, well shown still at Mt. Morris Park, at north end of Central Park, and on Morningside Heights." This language recalls aspects of Dr. Hunt's *crenitic* hypothesis, though its author would not endorse Dr. Hunt's very speculative views. Dr. Julien contends for a "vast dissemination of occluded igneous matter" in the schists of Manhattan Island, and apparently would refer the strongly biotitic (biotite is the black ferromagnesian mica) schists of Manhattan to the assimilation of diorite intrusive dikes (which are now supposed to be represented by the hornblende schists, see p. 96), from which both the iron and magnesium have been derived, which enter in the composition of the biotite mica. This theory involves the conception of the hornblende of the diorite being altered at the boundaries of the dike into biotite, and the dike becoming measurably converted into a biotitic gneiss or biotite schist, and the biotite enrichment of the mica schists, further away from the dike, being due to the hornblendic contents of the dike. This is certainly not always the case, as can be seen by examination of the hornblende schists (metamorphosed diorites) and their adjoining mica or gneiss rocks.

In this connection it is desirable to call attention to some interesting speculation of Mr. R. A. Daly, of the Canadian Survey (*Amer. Journal Sci.*, 4th Series, Vol. 15, p. 269; Vol. 16, p. 107, and Vol. 20, p. 185), who has defended the famous "assimilation theory" as to the origin of granites. The theory does not stand well among lithologists, but it has not been abandoned, either, by many distinguished students. It involves some fundamental assumptions if extended to the possible limits of its application, generally to acid intrusives. (An acid rock is a rock rich in silica, a basic, one not so siliceous, and carrying high percentages of lime, iron and magnesia.) The theory means the welling out and intrusion of a basic magma into acid rocks which may be crystalline schists and metamorphosed or simply consolidated sediments; the basic rock "assimilates" or digests by fusion and absorption the acid compound it invades, and there results an intermediate rock more basic than the invaded strata, more acid than the invading eruptive, and among such resultant rock *sequelæ* granites form a conspicuous class. If then it can be assumed that the underlying fluid rock masses of the earth are basic (ferro-magnesian, gabbroitic), that these invade or are mingled with acid sediments overlying them, the subsequently modified mixture, by separation, would yield "a thoroughly granular acid rock," and this in turn, as a granitic effusion, under the stimulus of pressure, would penetrate overlying fissures, faults, and cavities, or actually "stope" its way upward, melting and reinvolving superincumbent strata, and solidifying among these latter as granite dikes, buttes, and laccolites.

Acid or granitic effusions have been presented to us as vein masses in the rocks of New York. They have almost certainly at times been poured out in beds, which have again been lifted and folded with the inclosing metamorphic schists, and they, too, seem to have irregularly penetrated the schists, cutting them at various angles. It is permissible to introduce here this assimilation theory with reference to their origin, though the basic dioritic or gabbro-like intrusions—if the hornblende rocks and the altered amphibolite of the Manhattan area are so to be classed—have remained apparently their contemporaneous associates. (See pp. 97, 99.)

The many small meandering veinlets, mentioned above, which cross the gneiss or schist lamination and penetrate it in looped and bending streaks, were, perhaps, more slowly exuded from granitic magmas, and, as a group, are referable to the later stages of the complex's history. And, as has been suggested, they are also conceivably synchronous and congenital with the foldings which have fused the rubbings and schist walls, along cracks, into granitic intercalations.

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 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 Street and Central Park, formerly at the east end of Washington Bridge, while they are shown in the most wonderful confusion at 152d Street and 7th 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. 14, 15, 16.)

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 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 granulites 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

Fig. 16. North side of 152d Street. Close study of rocks, showing flexure.

Fig. 17. Contorted strata from east end of Washington Bridge, exhibited at the American Museum of Natural History, New York.

rock, now so familiar to us, yet, in some respects, so difficult of interpretation.

Heat from presssure, 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 making different local products, as the garnets, where lime prevailed; tourmaline, where iron and boron 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 probable that the *conformable* (see *ante*) granite veins were formed with the schists and gneisses. But it is conceded the larger granite stocks were igneous intrusions. 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 crystallization 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 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 (pegmatization). Not, indeed, that the secondary granite veins were intrusive, in the sense that they were filled from below from deep-seated magma, but that they represented refused gneiss which, along the openings and shearing faces, recrystallized as granite. (Fig. 20.) This is possible, as the chemical composition of granite and gneiss is 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 micaceous.

Segregation has 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 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

Fig. 18. Plicated Granitic Veinlet from West End Avenue, 63d to 64th Street, exhibited at the American Museum of Natural History, New York.

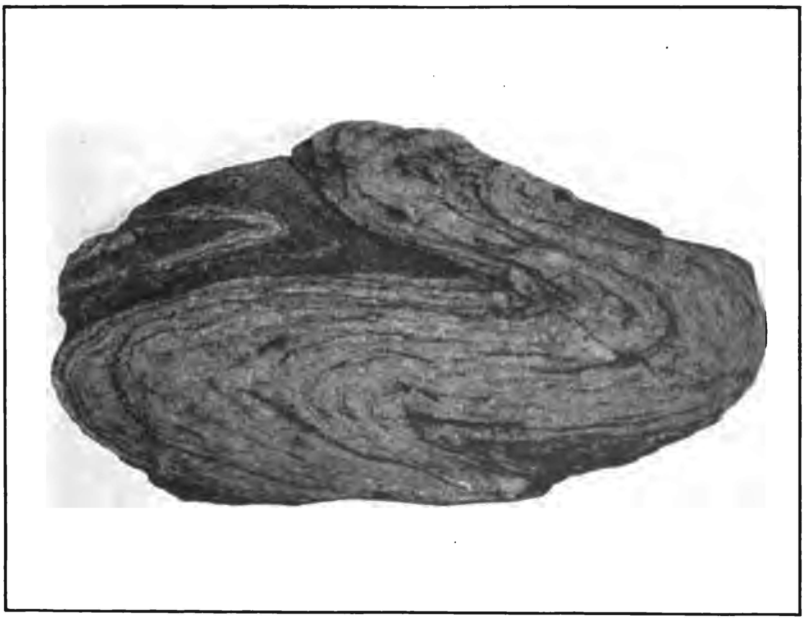


Fig. 19. Plicated strata from University Heights, exhibited at the American Museum of Natural History, New York.

Fig. 20. North side of 126th Street, a few feet west of Manhattan Avenue, showing granite vein and shearing.

Fig. 21. South side of 110th Street, near Columbus Avenue, showing folded granite vein in very micaceous gneiss. (The vertical lines are drill holes.)

easily reached example is in 110th Street, west of Columbus Avenue. (Fig. 21.) 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 overthrusts 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 of 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 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 Street and 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 Street, 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 Steet) 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 solidification, and offered greater resistance was it accompanied by ruptures and fissuring. The beds on Manhattan Island as seen to-day 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 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. 22) 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 author that these beds are Archæan, and that 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 center of coarse, pegmatitic granite as a vein core. There are here some undulating and twisted cross veins of granite.

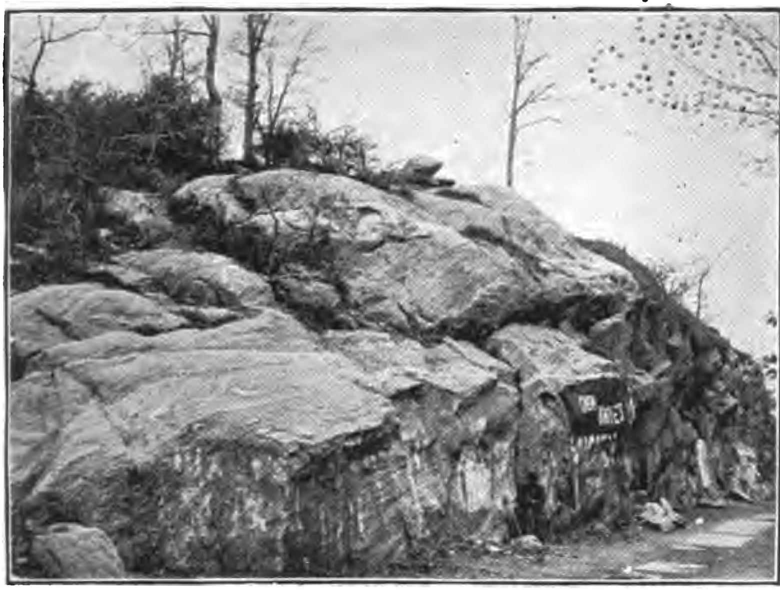


Fig. 22. Manhattan Avenue and 126th Street. Showing gneiss and veins and patches of granite.

Fig. 23. Hornblende rocks at 135th Street and Amsterdam Avenue.

Fig. 24. Limestone beds, 200th Street, west, showing dip to the Kingsbridge road.

Fig. 25. Railroad cut through gneiss hill north of Spuyten Duyvil Creek.

limestones are to be included, but it also may be instantly admitted that the weight of authority is against this view. In a general sense the Archæan may include everything pre-Cambrian.

This is an old view—and is disparaged because it is old. It has more recently been assumed that the crystalline schists of New England—much of them—the schists of Southern New York, those of Philadelphia, Baltimore, Washington, and Richmond, belong to the sedimentary series, in which all traces of fossils, if they formerly existed, have become obliterated through metamorphism. The Fordham gneiss of the Bronx, bordering the Harlem River, and on Manhattan Island at 152d Street, is frankly conceded as archæan or pre-Cambrian, and it is permissibly deduced that the gneiss rock brought up from deep borings on Manhattan Island is also Fordham gneiss or archæan. The Manhattan schists—gneisses and mica rock—overlying are referred to the Hudson River formation; and represent the metamorphosed shales or slates of the Hudson River beds, according to the authoritative view of the Albany geologists. It may be suggested, however, that there are no rocks certainly referable to the Hudson River formation south of the Highlands in New York —which are unquestionably Archæan—and the *progressive metamorphism* must be traced through the schists of Connecticut to the New England taconic slates and shales, while from a lithological point of view it appears unusual that andalusite should not occur more frequently in the Manhattan schists as a metamorphic sequelæ from altered slates, of which it is so highly characteristic. Rosenbusch has pointed out that it occurs far more rarely in the mica-schists and gneisses of the Archæan.

Professor Chas. P. Berkey, of Columbia University, has exhaustively studied the crystalline belt of rock from New York City to the Highlands proper, and his study, by reason of its exhaustiveness (under natural limitations), its care and discrimination, and the poise of judgment in its author, perhaps falls beneath a strictly determinative concluson. But it is intensely interesting and suggestive, and separated statements reopen the question of the geological position of the Manhattan succession in a manner, it would seem, not hostile to the views here advocated.

Professor Berkey finds a basal gneiss representing in general the whole Highlands region, and upon this *towards the south* his group of *Inwood Limestone* and *Manhattan Schists* gives evidence of complete uniformity, so that "it is the writer's opinion that there are two distinct groups of formations above the basal gneisses in the Highlands region. The older and more complex, wholly crystalline, at the base a limestone (Inwood), followed by a schist (Manhattan), both of *pre-Cambric Age, occupies together with the gneisses almost the whole of the Highlands and the southward extension to New York City.* The younger, a Cambro-Siluric series, with a thick quartzite always at the base (Poughquag), followed by a limestone (Wappinger), and completed by a slate (Hudson River), forms a continuous border *along the north of the Highlands.*"

FURTHER VIEWS ON THE GRANITES OF MANHATTAN ISLAND AND VICINITY AND THE SERPENTINE ROCKS

Dr. A. A. Julien has quite extendedly studied the granitic occurrences on Manhattan Island, and his views are embodied in a paper read before the American Association for the Advancement of Science in 1900. The granites on New York Island considered by Dr. Julien were the *pegmatites* or coarse granites, where the separate constituents (quartz, feldspar, mica) have a strongely marked isolation; that is, the quartz and feldspar and mica, instead of being intimately mixed in a ground mass of fine texture, form sensibly large areas adjoining and mingled with each other, and, while still a granite, have a very coarse structure. Many of the granites on Manhattan Island belong to this type.

He distinguished between two series of pegmatitic developments, and indicated that they were marked by a succession of intersections. The oldest series is the most extensive, and lies in the foliæ, or leaves, of the inclosing mica rock and assumes the latter's strike. The later or younger series cuts the schists in all directions and all inclinations. Dr. Julien avers that all the coarse granites of the island have been originally veins "segregated from a magna or igneous-aqueous emulsion," which probably means that these granites have crystallized from a viscous or semi-fluid rock paste, however that rock paste originated. In this crystallization they assumed a vein structure showing correspondent deposits on the two walls, or a comb structure with the less acid minerals on the outside and the more acid minerals at the center of the vein, with often also a concentration of minerals of rare elements (xenotime, monazite, allanite, etc.), in smoky quartz near a central suture.

But this original vein structure has been powerfully compressed in the mountain-making movements of the schists around it, and there has been fissuring, faulting, crushing, shearing "with development of aplite (a granite dike) refusion, and development of new phenocrysts (granite porphyry) and the generation of reaction borders outside of each wall of vein," or, in other words, the vein granites have assumed the nature and function of intrusive granites, and in the surrounding rock their heat has developed accessory minerals. Flowage occurred and the crushed vein matter of the granite became dike-like along the plane of the veins. But Julien insists that "in the most characteristic dikes the vein structure is rarely, if ever, completely obliterated." Dr. Julien's diagnosis is certainly not startlingly at variance with that given above, but presents the further conception of the vein-like nature of the New York Island granites, when first formed.

Such a view does not apply to the fine-grained granites, as the large development on the west side in the fifties, which has all the appearance of an intrusive rock, a welling out of a pasty or liquid mineral body.

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 Street and 60th Street, 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 eozoönal (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 Street between 10th and 11th Avenues, and it can be traced to near 56th Street by isolated knobs appearing above the level of the sidewalk and in backyards. 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 Street, 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 neighbor.' 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 eozoönal-like portions, which would seem, so far as their microscopic (in hand fragments) appearance goes, to easily warrant their reference to a close relationship with the Canadian rock containing that debatable organism.

"Cozzens, in his Geological History of Manhattan or New York Island (1843), p. 12, refers to this locality, saying: 'Between 54th and 62d Streets the shore and 10th Avenue 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 syenite, 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,' eozoönal 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 anthophyllite alluded to above, but on visiting the locality on 59th Street, 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 showed a vertical face where eozoön 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 Street, 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 ANTHOPYLLITE, SERPENTINE, EOZOÖNAL 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 Street. Anthophyllite and actinolite boulders have been found southeast of the 59th Street 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 Street; 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 11th Avenue. Dana regards this serpentine locality as related to the limestone areas in Westchester County, in which serpentine is known to occur. The name ophio-calcite, applied to some of these serpentinized rocks, is, in strictness, inaccurate. A true ophiocalcite consists of an original limestone in which amphibole or pyroxene has changed to serpentine. In the 58th Street rock the calcite is secondary, being a chemical deposit formed in the process of an original amphibole changing to serpentine. In both cases the physical results resemble each other.

Dr. Julien visited this locality in West Fifty-fourth to Sixty-third Streets as early as 1878, and his observations, in field notes, indicate "a basin-like depression, with swampy bottom and deeply gullied sides about Fifty-eighth Street, which seemed to have been excavated in the softer material during some ancient time by a small stream running westward to the Hudson." His allusions to the serpentine appear to be included in these words: "Blackish-green, tremolitic, serpentine (spotted with greenish-gray altered actinolite), about 40 feet, inclosing thin sheets of tremolite schist; hydrated tremolite schist (hydrous-anthophyllite) at least 60 feet, inclosing many layers and amorphous masses of serpentine, ophio-calcite, compact tremolite rock, and sometimes asbestus."

M. A. Yeshilian assures me that boulders of asbestus and serpentine were found along the west side of Amsterdam Avenue above 165th to 181st Streets.

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 Street and Harlem Heights, at 94th Street, between 4th and 5th Avenues; hornblende schist, with crystals on the surface, at 80th and 81st Streets and 9th (Columbus) Avenue, now built over; hornblende gneiss, with quartz veins, at 116th Street and Columbus Avenue; hornblende gneiss penetrated by the Aqueduct shaft at 165th Street and Amsterdam Avenue, at 190th Street and 10th (Amsterdam) Avenue, here enfolding garnets; schist, with scapolite, at 93d Street 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 becomes 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.

DR. JULIEN'S ESSAY

Recently a very extended study of these hornblendic rocks has been made by Dr. A. A. Julien, which has emphasized the interpretation of these beds as intrusives, though not casting aside as unwarrantable or untenable the view of their possible sedimentary origin. Dr. Julien especially studied those which are found north of 44th Street, and many localities indicated on the map accompanying this paper are now covered over by buildings.

Julien points out, what has not been hitherto clearly indicated, that the hornblende rock (quartz diorite or hornblende schist) is sometimes found in intercalated zones, sheets, or ribbons in the island gneiss rock, showing "more or less disturbance, flexure, and even zigzag folding, with variations in thickness, and frequent passage at their margins into vaguely defined and crumpled layers of biotitic gneiss." These occurrences differ from the clearly defined beds, separating the gneiss strata. They are mingled in with micaceous rock, and have been penetrated or suffused with coarse granite seams, the complex, where this is evident, varying in mineral composition, becoming (at the point studied), as Julien describes it, a "hornblende gneiss, a biotitic hornblende schist, a biotitic schist, and dark, micaceous gneiss, richer in biotite than the contiguous country rock."

Class Direction.—The teacher is recommended to examine a typical locality at the southwest corner of West 119th Street and Morningside Avenue. There is here a face of micaceous gneiss with granite veins, lenticles, and veinlets, through which on the foliation planes run *nine parallel sheets* of black *hornblende rock.*

Julien's microscopic study of a thin section of *hornblende schist* showed "hornblende scales largely predominant, with more or less hematite and zoisite included, or around their margins, and separated by little patches of a limpidly clear and colorless mosaic of feldspar and quartz. As accessories, biotite, magnetite, zircon, and pyrite also occur."

The *hornblende gneiss* is more finely granular, and is made up of alternate lamellæ of black hornblende, and of a gray-white mixture of quartz and feldspar, with biotite mica, and greenish-yellow epidote in seams—especially where the gneiss has been crumpled or distorted.

In this rock hornblende amounts to from 30 to 50 per cent., quartz 15 to 30 per cent., feldspar 10 to 20 per cent., garnet occasionally as high as 5 per cent., while biotite, menaccanite, and pyrite and red films of iron oxide are present. There is associated with this in Dr. Julien's view the epidotic variety of this hornblende gneiss, in which the epidote may rise to 15 or 35 per cent. of the *volume.* In the hornblende gneiss there is a greater proportion of feldspar, in the hornblende schist is much less.

Notable exposures of hornblende rock are at West 119th

Street, where the bed has been greatly crumpled, folded, and even wrinkled, also at West 135th Street, at 7th Avenue, south of McComb's Dam bridge on the Harlem River, west side of St. Nicholas Avenue, about West 138th Street, where there is a vertical mass 3 to 4 feet in thickness forming a wall along the sidewalk for more than 60 feet. Dr. Julien describes a fault vein at this locality 2 feet wide "filled by a friction breccia made up of angular fragments of the hornblendic rock, inclosed in brownish-white quartz, the walls of the fracture lined by hackly projections of the torn rock along both sides, as if they had been wrenched apart and rubbed together" (*reibung-breccia*).

There is an immense bed on Spuyten Duyvil Creek, which is injected with vein matter of quartz and coarse granite material. Hornblende schist occurs at West 125th Street between Claremont and Riverside Avenues. There is a hornblende rock exposure on the Speedway at 186th Street and Harlem River, a hornblende schist in Fordham at Tremont Street, with epidote at West 135th Street, at 11th Avenue, a similar rock at 100th Street and 5th Avenue, in which under the microscope the thin section reveals *actinolite* rods and scales, with quartz and feldspar.

OTHER SCHISTS

Associated with the hornblende, and regarded by Julien as derivative from them, are actinolite and tremolite beds. An example of the former is at West 78th Street near Amsterdam Avenue, and at West 155th Street west of 10th Avenue, at Trinity Cemetery. Julien has thus described it: "This consists of a fibrous, laminated rock of yellowish green color, made up almost altogether of blades of actinolite, rarely exceeding 2 or 3 millimeters in length, parallel to the foliation. The intervening white seams, often 1 to 10 millimeters thick, are occupied mainly by granules of quartz, but in part, at the West 155th Street locality, by flakes of a pinkish white mineral of aluminous odor on moistening and somewhat harder than kaolin. Some planes are rich in glistening scales of biotite."

There is noted a tremolitic schist at West 59th Street, between 5th and 6th Avenues, which "is a finely fibrous, grayish white schist, resembling closely in texture and structure the black hornblende schist in the vicinity, but here made up entirely, to the eye, of parallel blades and fibres of tremolite, tightly compacted, with many surfaces and division planes stained by reddish and yellowish iron oxide."

Tremolite and actinolite (both of these minerals, along with hornblende, represent divergent chemical aggregates of the generalized species Amphibole) occur at the Serpentine (ophiocalcite, p. 47) locality in West 58th and 59th Streets, on 10th and 11th Avenues. The rock here showed various phases of aggregation, finely granular and hard to coarsely schistose, for the most part made up of tremolite blades, with scales of talc chlorite and needles of actinolite.

To this section belong the anthophyllites (see *ante*, p. 92), and in this area Dr. Julien, as early as 1878, when there was far less occupancy of the ground by houses, made observations which indicated the existence of two beds of hornblende rock, probably not at the same horizon, but one above the other, bent and folded, but interleaved with the prevalent micaceous beds. These bornblende beds thinned out on 57th Street, thickened on 59th Street, and continued westward, and according to this authority, the tremolite and actinolite beds on 10th and 11th Avenues were "but a facies of the thick bed of hornblende schist between 9th and 10th Avenues."

Connected with the occurrence of hornblende rock on Manhattan Island is the interesting feature of its very common plication. Dana has, indeed, observed that "the presence of hornblende or hornblendic schist appears to have often determined a crowd of subordinate flexures and contortions in the beds and a loss of distinctness in the minor layers. I have explained this on the ground that hornblende is relatively a fusible mineral, and in consequence beds that become hornblendic, in the metamorphic process, easily soften and bend."

Those authorities assuming the igneous origin of the hornblende rock, as dikes, dissent naturally from this explanation, and Julien, acknowledging the evident original plasticity of these hornblende masses, has in a rather generalized way attributed it to condensation by pressure in the crustal shortening, to softening by heated waters and mineralizers, and to the internal lamellar structure of its components, permitting slipping, twisting, etc. To me it seems that here this admirable observer fails in conclusiveness.

THE IGNEOUS ORIGIN OF THE HORNBLENDE ROCKS

Dr. Julien rejects the reference of the hornblende rock to the metamorphism of aluminous clays or shales holding a high percentage of iron oxides, lime, and magnesia, because an analysis of the New York hornblende rock does not agree with the analyses of hornblende schists certainly derived from such sediments. He also dismisses the suggestion that the hornblende rock represents changed layers of volcanic ash simply on the same ground, that the analysis of such tuffs does not correspond with the table of composition assigned to the Manhattan Island rock by Dr. Jouët, of the Columbia School of Mines.

He further objects to the hornblende having originated in the change of magnesian calcareous and iron constituents in a dolomite or limestone. In this process the limestone became *amphibolized* or changed in part to amphibole, of which hornblende represents a highly ferriferous variety. After such a change the removal of the residual calcite or dolomite by solution would leave a hornblende or amphibole rock. An extensive series of comparisons convinces him that the hornblende rock of Manhattan Island did not originate in this way.

By exclusion our author is driven to the third hypothesis, *viz.*, metamorphism of basic igneous intrusions, or the change of what were originally lava-like flows, after cooling and consolidation, through subsequent molding and plasticity in the process of metamorphism, into hornblende schists and gneisses.

His support of this assumption rests essentially upon three arguments—chemical composition of the hornblende rock, physical features, and "contact alteration."

As to the chemical composition of the hornblende rock, it was carefully determined by analysis, and ingeniously redetermined by Julien by a process of ocular inspection under the microscope and with the auxiliary aid of photography (see original paper), and found to very closely resemble the analysis of a black hornblende from Vesuvius, Italy, of unquestioned volcanic origin.

As to their physical features, the beds of hornblende should be dike-like, to sustain their claim to an igneous origin, having been inserted by protrusion along the beds of adjoining sediments. As Julien remarks, "few continuous outcrops of our schist have reached 100 yards in length along the strike." They appear like interposed lens-shaped masses, thickening at the center, thinning at the edges. There are, however, exceptions. At West 135th Street, near 10th Avenue, there was a sheet that formerly reached from 133d to 138th Streets, or more than 1000 feet. The hornblende at Spuyten Duyvil extends to-day for more than 1200 feet. The amphibole rocks from West 54th to 63d Street at 11th Avenue covered more than 2000 feet, and these rocks, as shown above, Julien regards as a phase of the hornblende series. Repeated outcrops of hornblende rocks along 97th to 99th Street from river to river suggested "the inclosure of a nearly continuous sheet of hornblende gneiss from river to river, brought up to view on one side of every anticlinal fold and descending on the other." Julien further says: "Combining this evidence with that from the cross section at 58th to 59th Street, there is reason to assume the existence of at least one interrupted sheet, here and there split up into thinner layers, closely adjacent, or perhaps two horizon planes in the Manhattan series, over which this basic material has been spread or throughout which it has been injected. In other words, a large number of these outcrops plotted on the map after all represent but one or two intrusions."

Again a natural objection to these hornblende rocks being regarded as intrusive dikes is their generally exact lamination in conformity with the enclosing rocks, and then folding apparently in unison with these latter. Arms (apophyses), however, of the hornblende rock projecting into the micaceous gneiss have been found. (See Morningside Park and near 119th Street.) It is quite clear, however interpreted, that the hornblende rock shared equally with the mica rock around it in the curvature plication and lateral compression which attended the upheaval of the latter from its horizontal position into vertical anti- and synclinals.

Julien continues his argument with apparent evidence of "contact alteration," by which is meant changes in the enclosing rocks of an igneous dike, produced by its heat and mineralizing agency. If such contact alteration could be established it would reinforce the view taken, that these hornblende rocks are intrusive. Julien refers to the very evident cleanness of edge of these hornblende layers, their delimitation from the mica rock about them being clearly and impressively sharp. There is generally absent any convincing proof of contact alteration, but Dr. Julien claims that "a recent reexamination of sheets of hornblende schist, 2 to 18 inches in thickness, at the northeast corner of West 186th Street and Wadsworth Avenue, revealed an abundance of biotite and also of garnet, up to 1 centimeter in diameter, both within the hornblende schist and in the contiguous pegmatitic gneiss, but only within a distance of 2 or 3 centimeters from the contact line." This seems to deserve some weight.

In rock dikes there are apt to be coarse crystallizations, and Julien supposes some very indefinite "obscure dark blotches or flattened flakes, of rhombic, rectangular, or ovoid outline, 1 or 2 centimeters in length," represent the altered nuclei of such minerals in the hornblende rock.

The evidence for the igneous origin of the hornblende beds on Manhattan Island has been shrewdly and cumulatively prepared, and taken in conjunction with the unquestioned volcanic nature of beds at New Rochelle, Rye, Cortlandt on the Hudson, etc., and the widespread occurrence of such intrusions elsewhere in terranes of a similar or identical lithological facies, there is certainly scientific propriety in referring the hornblende schists at least to an igneous source.

EPIDOTIC BEDS

Epidote in considerable developments is found in conjunction with the hornblende rocks of the island—seams, greenish-yellow and some inches in width. It can be seen on the north side of West 135th Street, west of Amsterdam Avenue. "Here," says Julien, "in the huge crumpled mass of black hornblende schist the bright greenish-yellow seams, 2 to 5 centimeters in thickness, consist largely of epidote intimately mixed with quartz and partly or wholly replacing both feldspar and the original hornblende." (Fig. 23.)

THE LIMESTONES

In the third topographical section of Manhattan Island, that extending from 110th Street 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 Street to 130th Street 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 Street (Fig. 24) 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 feet of the little church at the entrance of the Inwood ravine or Dyckman Street. 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. 25), 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 County (Dana). A dominant point of interest from which topography of this section is well descried is at the end of the Bolton Road leading up from Dyckman Street, and beyond the House of Mercy, before the descent is reached which plunges in Spuyten Duyvil Creek. In the aqueduct shaft, at 180th Street, between 10th Avenue and the Harlem River, at 165 feet below the bed of the river, at its center, or 465 feet below the level of 10th Avenue, coarse and compact limestone was taken out.

This limestone underlies the Harlem River, and is produced in long prolongations underneath 4th and 5th Avenues (at 132d Street) and also under 8th Avenue, interrupted by gneiss, which appears to hold it in synclinal troughs, while in

Westchester County, both at Westchester and Eastchester villages and at Mott Haven, Morrisania, and Tremont, it is found, and is thence apparently divergently produced, being noted at Sing Sing, Sparta, Dobb's Ferry, Peekskill, Verplanck's Point, Tarrytown, and White Plains.

Professor Dana, in a series of elaborate observations, has undertaken to bring this Manhattan limestone into structural continuity with the Taconic marbles and schists, or that range of metamorphosed rocks which reaches northward through western New England. He would thus assign a Lower Silurian or *Ordovician* Age to the Kingsbridge rock. The evidence does not seem all exhausted yet, but there is a growing inclination, at least, to give these limestones a possibly lower place in the geological column than the rest of the

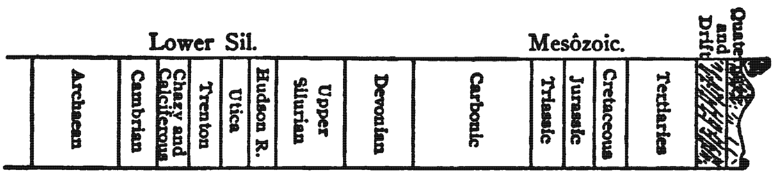


Fig. 26. Table of Formations.

island, making the *Manhattan* schists Hudson River. (Fig. 26.)

The assumption that the limestone is later than the gneiss does seem, in a measure, controverted by the facts that first, the limestone in its southern prolongation at 3d and 4th Avenues and at 6th and 8th is so intermingled with the gneiss as to become itself schistose or laminated—a sort of gneissoid limestone—or, to read the inferences inversely, the gneiss has become so calcareous as to appear a limestone; and, secondly, the observation made by Stevens, and apparently repeated by Kemp, that at 3d and 4th Avenues the limestone is interbedded with two strata of gneiss, one above and one below; and again by Stevens, that at 6th Avenue, in West 132d Street, the limestone is thrown upward in an arch with "the gneiss reposing conformably upon it," all of which conditions would plausibly argue a contemporary origin for both gneiss and limestone.

As to the second group of facts (?), there are some doubts permissible as to the construction given to the relations observed, inasmuch as at some points, at least, the limestone overlies the underlying gneiss; and, as to the first, the intergradation of gneiss and limestone, two sediments collected at widely separated periods would at some subsequent moment, when metamorphism, folding, and compression began, be, at much of their surface of contact, thrust into each other, and become insensibly but thoroughly mingled. Indeed, Stevens avers that "the thrust of large masses of limestone into the solid gneiss was seen, crushing and grinding the latter as it passed, showing that the rocks were hardened when the folding action took place and the thrust was made."

Late observations, perhaps, acceptably demonstrate that the limestone beds of Manhattan Island underlie the mica rocks, the schistose gneisses, called the *Manhattan schist,* while conclusively *over*lying the Fordham gneiss.

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 limestone and are of a different age.

In this connexion M. A. Yeshilian has observed that at Walton Avenue and Tudor Place, near 167th Street and

Jerome Avenue, a section of limestone "plainly rolls over the schist, while a little way below, on and near Jerome Avenue, a considerable series of limestone layers dip eastward, showing overlap." Mr. Yeshilian considers the contour of contact between the limestones and the schists a fault line at Inwood (Dyckman Street), towards the Hudson, at Fort George, and along the Harlem River defile at High Bridge and Washington Bridge. In the limestone at Girard Avenue and 167th Street, according to this observer, there are very noticeable enclosures of gneiss or schist in the limestone.

Mr. E. C. Eckel has published his observations of 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. On Post Avenue, just north of 204th Street, the dolomite (limestone) flooring the lowlands appears in platy beds, in thin sheets, lamellarly curvilinear, and forms a bank (12 feet high) along Post Avenue (Fig. 27), with calcareous sand, representing subaerial erosion, on the surface. North of this point, a few feet, is a granite intrusive developed in some magnitude on 204th Street, east of Post Avenue. It is a coarse granite, flexed, and dislocated, much spotted and impregnated with tourmaline.

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 Professor 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. 24), the Manhattan schists, Hudson River, and the Fordham and Yonkers gneisses archæan.

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 Professor 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.

The limestone of Manhattan Island and its identical prolongations, northward in Westchester County, illustrate very forcibly a stage in metamorphism. Throughout the original calcareous and magnesian beds were disseminated, in irregular sporadic and adventitious mixtures and deposits, siliceous, ferruginous, aluminous, and alkali sediments which quickly upon the supervention of chemical opportunities, combined with the bases of the calcareous muds to form various silicates now found distributed in nests, broken reticulated seams, or dispersed scales and individuals in the dolomite. Such minerals are tremolite (malacolite), diopside, biotite, tourmaline, while silica crystallized in geode-like cavities as smoky or pellucid quartz. The chemical opportunity was the moment when sufficient mobility was given to the elements by heat to enter into new combinations and form these accessory mineral species at the same time that the calcareous and magnesian muds hardened and crystallized into their present form.

WATER-WAYS

The different sections of Greater New York are separated from one another by water-channels, all of which are subordinated to the large central stream of the Hudson River. The Hudson River, as a topographical feature, quite overshadows the neighboring tidal affluents. But at the city of New York this river has utterly lost its fluviatile character. It has been drowned, absorbed, and overwhelmed by the invasion of the ocean; along with the other water-ways it is an aisle over which the ingression of the sea is marked by two maxima and two minima heights daily. Before this practical submergence, when the shore lines were more elevated, its expansion into any lake-like basin, such as the Upper Bay, was probably far less conspicuous. It then became, indeed, a conditioned current, pressing its way between the headlands, facing each other, of Long Island and Staten Island as it escaped the coast line into the Atlantic Ocean.

Its former course was prolonged over a wide coastal plane reaching the edge of the continent some eighty miles from the Narrows. It is now at this point submerged by the invading waters of the ocean, which form of all the channels about New York, as well as the lower reaches of the Hudson, a network of tidal areas. The coast has subsided, and the estuarine limits of the Hudson, the Passaic, Hackensack, and Housatonic Rivers have been pushed inland.

The depth of water in the Lower Bay, south of the Narrows, over the shoals or sand bars, is generally 8 to 18 feet, and in the channels which thread or divide them it is 21 to 30 feet deep. Nearer the Narrows the water deepens to 24 and 72 feet; in the Narrows the depth exceeds 120 feet, and thence northward in the main avenue or *tirage* of the Hudson there is found from 30 to 72 feet, with lateral shallow overflows towards the New Jersey and Long Island shores, where the water is barely more than 18 feet deep.

The overpowering influence of the ocean in modifying its issue has been repeatedly pointed out as the tides and storms swing back and forth the heavy burdens of sand along the coasts of Long Island and New Jersey. Professor Lewis M. Haupt has discussed the projects which have been carried on by the general government for improving the channels of the Lower Bay. Up to 1886 the ruling depth on the bar was 23.3 feet at mean low water, which permitted the passage at high water of a vessel drawing 27 feet. Professor Haupt desired to influence the government to adopt his method of improving this entrance by natural forces. This was unsuccessful. It was concluded to resort to dredging to create a 30-foot channel, 1000 feet wide, which had been secured and maintained after the removal, up to October, 1891, of 4,875,079 cubic yards at a cost to date of $1,967,111.82. These depths not meeting the requirements of the port, facilities were then increased by the opening of the Ambrose channel, seven miles in length, crossing the central part of the bar, by dredging therefrom 42,500,000 cubic yards, under the provision that it should not cost more than $4,000,000, or less than ten cents per yard.

Professor Haupt, by means of charts covering a period of 125 years, has shown that the inlet to Jamaica Bay has moved westwardly seven miles in that time, and that the deposits which were formerly arrested in that bay have now drifted past and are rapidly approaching the outer scarp of the New York bar. This one bank of sand contains some 65,000,000 cubic yards, while on the other flank the spit at Sandy Hook has advanced about a mile and is now moving into the bay, where it deposits a half million yards on the point every year, to say nothing of the sand held in suspension and which has been removed by dredging. The great quantities of drift thus advancing steadily into the entrance are becoming a serious menace to the harbor.

The Borough of Richmond (Staten Island) is separated from New Jersey on the west by the channel of the Arthur Kill, and on the north by that of the Kill van Kull, which latter has a depth of 30 feet.

Manhattan 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 shore shells (*Mactra lateralis* Say), etc. The soundings for the Pennsylvania Railroad tunnel showed an average thickness of the mud bottom to the rock of 132 feet.

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 East River has an average depth of 50 feet, with some remarkably cavernous holes at Hell Gate (150 feet). The Harlem River and Spuyten Duyvil Creek are only 12 to 18 feet deep. Rock bottom, however, is far below.

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 substances 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, much of which may be derived from dissolved limestone. Professor William H. Hobbs read a paper in 1902 before the New York Academy of Sciences on "The Geology of the River Channels in the Vicinity of New York," in which some original views in regard to the origin of the water-ways immediately bounding New York Island were quite emphatically and lucidly, if not convincingly, developed. Professor Hobbs believes that New York Island represents a topographic crystalline block, outlined by faults and displacements. Its western edge along the Hudson River is thus defined; the Spuyten Duyvil and Harlem and East Rivers have been determined by joints and displacements. He thinks no "correspondence can be established between the directions of the belts of limestone or dolomite and of the New York water front, except within the stretch from Kingsbridge to Macomb's Dam Bridge. Along this line, too, the observed facts point to the occurrence of a narrow strip of limestone dropped down between nearly vertical faults. The sections of the Harlem River which are furnished by the bridges across it show clearly that it is not a simple erosion valley resulting from cutting by the stream. The bed of the stream is marked by sudden change of level, and the Harlem seems to have chosen its course quite independently of the position of ridges of the harder gneiss. Under the East River limestone has been found at but two localities—under the channel east of Blackwell's Island and in one of the drill holes underneath the Manhattan pier of East River Bridge No. 3. The limestone east of Blackwell's Island is enclosed between parallel fault walls, and appears to have been dropped down along them. The numerous occurrences, however, of gneiss and gneiss only along, in, and under the East River leave little doubt that the main portion of the bed is composed of this rock" (abstract). There seems a strong temptation to accept in a measure Professor Hobbs' view. It would appear impossible to endorse all of its implications. It cannot be well denied that there is a cross fracture at Spuyten Duyvil, and that it may have occured in such a way and under just such a strain as would throw the island of New York slightly southward and downward, lowering its southern point and invoking, as a consequence, some lateral wrenches, as the Manhattanville cross valley, and bringing about faults in the channels of the Harlem and East Rivers. But the deepening and extension and widening of these river heads must have been the result of stream erosion, and done at a time when the land was more elevated than at present, and it seems likely that at that higher elevation the course of the East River, at least, was a tumultuous one, broken by rapids and falls.

And in considering this hypothesis it should be recalled that the dropping down and out of rock sections two to five hundred feet involves abyssal conditions in the crust of the earth not to be lightly invoked. In mountain ranges there do, indeed, occur displacements of extraordinary dimensions, but this amounts to reshifting of elevations already above sea-level, and accompanied with uplift and overshove crumpling and crushing. Dr. Hobbs' view seems to contemplate a falling out of blocks along joint walls, as, in a tile mosaic, one tile may sink below the level of its neighbors. The memoirs and papers of Professor J. J. Stevenson have fully displayed the wonderful extent of the faults in Tennessee, Virginia, and Pennsylvania, with differential changes of 500, 2,400 and 2,800 to 12,000 feet, and these have largely been considered by Professor Stevenson as "cracked anticlinals." Professor Stevenson refers the time of these faults to the Mesozoic (Triassic).*

In 1895 the tunnel for the East River Gas Company from East 70th Street, underneath Blackwell's Island to Ravenswood, Long Island, was completed. The tunnel is 2,516 feet long, and about ten feet and a half in diameter. The rocks met were mica schist, "much contorted, but with a well-marked general dip of about 80° west" (Kemp), kaolin with garnet and biotite, quartz, decomposed mica schist, a fissure filled with soft mud, river sand, and near the east shore of Blackwell's Island ten to twelve feet of dolomite. Beyond this, compressed in a synclinal fold, were mica schist and again white "crystalline dolomite precisely like the outcrop at Kingsbridge" (Kemp). If it is assumed that this dolomite lay in the flooring of the west channel at this point, then, as Professor

*An item of interest to students of our Manhattan geology is thus recorded by Professor Stevenson: "The crushing at several localities near Clinch River is excessive, and at one locality the shales are folded as closely as micaceous shales on Manhattan Island, but they show no evidence of metamorphism."

Kemp says, "It must have been a shallow trough now worn completely away, but its presence would simplify the problem of the development of our local drainage lines on the east side of Manhattan Island; they would then be uniformly due to the relatively easy erosion of limestone." There are yet, however, some elements of proof lacking.

The shores of Greater New York embrace those with a rocky nucleus, as those about Manhattan Island, and those of sand, clay, and earth, as those along the coasts of Long Island and Staten Island. The latter, from the softness of their material, have been shaped into generally smooth contours with exceptional prolongations and outlying shoals and bars. These undergo mutations with the storms and tides as the sand, whirled and drifted, moves bodily up or down the coast.

The former, being more resistant from their mineral compactness, although far older in time, are margined with islets, prominences, inlets, and knobs. The islands and reefs in the Upper Bay are such rock nuclei; the strips of hard gneiss forming islands in the East River and the immature coast line further east towards New Rochelle fall into the same category.

There is discovered in the submarine survey of the sea-bottom near the entrance to the New York Lower Bay a well-defined submarine valley, also an area of clay bottom extending about one hundred miles seaward, and, thirdly, a deep ravine at the edge of the continental slope. There was formerly found in this region a series of "deep mud holes" in a straight line off the entrance to the harbor. Later these mud holes were believed to indicate part of a submerged channel continuous with the axis of the Hudson River valley. Ten nautical miles east by south from Sandy Hook there is a depth of 114 feet, in a depression or gulch which extends southerly about ten miles, then turns to the eastward for five miles, and maintains thereafter a straight course of fifteen miles to a deeper ravine crossed by a bar, which seems to lie across the latter's mouth at its immediate debouchment into the deeper ocean. This depression or gulch is a channel unmistakably walled in or banked, and the width of the channel widens and narrows, as might be expected in a river course making its way through obstructions, at angles or bends.

The clay bottom of this channel seems to be regarded as due to the extension seaward of the Tertiary "sandy clay strata" of New Jersey, or the channel itself represents the movement seaward through its eroded layers of the Hudson River over the coastal plane. At the same time it seems probable that through a large part of the region traversed by the Hudson River channel the stream has made its way through glacial drift, superimposed upon the Tertiary clays, etc. This channel, as mentioned above, deepens again from the distance of eighty-five miles from Sandy Hook to the one hundred and fifth mile from the same point. This seaward extension is characterized by an increased depth, beginning with 360 feet and increasing to 1,200 feet within the first mile. It is three miles wide. The greatest depth of 474 fathoms is at the outlet. Here occurs a bar with a depth of 200 fathoms. This very deep gash is regarded as a submerged fiord into which the channel, which precedes it from the Lower Bay outward, empties. However interpreted, this remarkable trough and its sudden and extreme deepening into its cañon-like embouchure into the ocean certainly indicate the early prolongation of the Hudson River over a widely extended coastal region, composed of cretaceous and Tertiary clays and glacial detritus, resting on a foundation of crystalline rocks, at a time, of course, when the whole region was elevated above the waters of the ocean which now cover it.

The foregoing details of the coastal submarine conformation of the Hudson River by Lindenkohl has been modified by Dr. J. W. Spencer to this extent: "Lindenkohl thought that the cañon was terminated by a bar, but Dr. Spencer has determined that no bar exists, and that the cañon cuts through the edge of the continental bench about eight miles farther. It then widens to a valley, which can be readily recognized for an additional twelve miles and to a depth of 9,000 feet at a distance of 71 miles from the head of the submarine channel near Sandy Hook. The cañon is double, the upper part being four miles wide, while the inner, lower, more sinuous portion is less than two miles across. The period of great elevation, probably coincides with that of the early pleistocene. Since that time there has been a subsidence to somewhat below the present level, followed by a re-elevation of 250 feet, as seen by the shallow channels of the continental shelf. The region is now sinking at the rate of two feet a century, and is undergoing other and less important changes."

ROCK SOUNDINGS FROM HOBBS' ESSAY

(ORIGIN OF THE CHANNELS SURROUNDING MANHATTAN ISLAND, NEW YORK)

SPUYTEN DUYVIL BRIDGE, HARLEM RIVER, rests on piles; wash borings to rock, 94 to 124 feet.

WASHINGTON BRIDGE, HARLEM RIVER, middle pier sunk by caissons to "an irregular rock, partly gneiss, partly marble, with veins and pockets of very hard quartz."

HIGH BRIDGE, HARLEM RIVER, three central piers on limestone.

McCOMBS DAM (CENTRAL) BRIDGE, piers on gneiss.

NEW YORK CENTRAL RAILROAD BRIDGE, piles go down 120 feet, but do not reach bed rock.

ONE HUNDRED AND FORTY-FIFTH STREET BRIDGE, piers (4) on limestone, (1) on hard pan.

RAPID TRANSIT TUNNEL, through limestone.

PARK AVENUE RAILROAD BRIDGE, gneiss.

THIRD AVENUE BRIDGE, gneiss.

SECOND AVENUE BRIDGE, no rock encountered.

WILLIS AVENUE BRIDGE, boulders and limestone.

ONE HUNDRED AND TWENTY-FIFTH STREET, gneiss.

PROJECTED HELL GATE RAILROAD BRIDGE, gneiss from near surface to 100 feet below mean high water.

HELL GATE REEF, gneiss, as on Ward's Island.

EAST RIVER GAS COMPANY'S TUNNEL (Mr. Davies' report), "Under the New York end of the tunnel is highly micaceous gneiss rock. Just outside of the pier line it intersected a fissure. . . . Under the east channel is a seam of about 350 feet of dolomite, bounded on both sides by fissures of completely decomposed (and soapstone-like) mica schist. . . . The dip of these fissure faces is about 22 degrees off the vertical. The strike is slightly west of north."*

BLACKWELL'S ISLAND BRIDGE, gueiss

WILLIAMSBURG BRIDGE, gneiss.

EAST RIVER BRIDGE, THOMPSON STREET, gneiss.

BROOKLYN BRIDGE, gneiss.

RAPID TRANSIT TUNNEL, EAST RIVER, gneiss.

WELL ON GOVERNOR'S ISLAND, "micaceous type of gneiss" for 1,800 feet.

JERSEY FLATS, gneiss "nearly vertically stratified." "On the south side of Ellis Island piles were driven into hard bottom at depths ranging from 16 to 23 feet at mean low water. No rock was encountered. Buttermilk Channel has been dredged to a clean depth of 26 feet below mean low water without uncovering rock in place."

The shaft sunk by the Pennsylvania Railroad Company on the Manhattan side of their North (Hudson) River tunnels was in good rock, said to be by Mr. Forgie† "of good, sound granite." Outside of this immediate edge of the island the engineers fully anticipated a problem of some complexity, in the composition of the soft bed-filling of the Hudson River, as "involving different kinds of soil (quicksand and gravel, loose earth and rock) and the transition from one to another," which resulted in a carefully and entirely successful shield-design by Mr. Forgie. Chief-Engineer Jacobs has testified that the sediment, or mud, in the Hudson River "was found to be on the average about 132 feet deep"—that is, he explained, it is about that distance from the bed of the river to the rock formations.

Hugh T. Wreaks, engineer of the Underwriters' Laboratories of this city, has thus described the shore conditions along the North River:

* Specimen of "dense basalt" taken from Man-o'-War Reef, East River, was shown by Julien to be a drift fragment of Palisade trap.

† The construction of the Pennsylvania Railroad tunnels under the Hudson River at New York City, by James Forgie; Engineering News, Vol. 56, p. 603 *et seq.*

"The physical characteristics of the North River must regulate the class of construction which can be put there. At the Battery, rock is found at comparatively moderate depths (less than fifty feet) below mean high water, and the depth of the rock does not change materially below Barclay Street. Above Barclay Street the rock becomes deeper, but continues at a depth not far from eighty feet at the bulkhead line and somewhat less on the pierhead line to Leroy Street. The depth then increases. It is 124 feet at Christopher Street and nearly 200 feet at 14th Street, and these extreme depths continue to 34th Street. Above 34th Street the rock rises rapidly on the bulkhead line, but continues very deep on the pierhead line. Over this rock is a deposit which, though it contains in some places fairly good sand, may generally be described as mud. It has practically no carrying capacity, and any weight resting on its surface sinks into it at once. Any construction built along the North River, from Barclay Street to 34th Street, must be built in this mud. It is entirely a case of flotation. The construction can be sustained only by making it a part of the mud. Above 34th Street the same condition may be said to exist with the piers, although better foundation can be found for the bulkhead wall."

If speculation may be permitted, it seems probable that the primitive condition of Manhattan Island, taken as inclusive of the present water-ways, had resulted from subaerial weathering with trough and valley creases formed by differential removal, perhaps to some extent by faulting; that it was sculptured at a time when it was very much above its present level, and a very moderate topographical unit in a vastly extended primitive terrane north, east, and south, and west, into *inselberge,* irregular hillocks, longitudinal ridges with drainage courses on the east and west. These drainage courses were generally north and south courses. They converged on the east into the East River, with its extension eastward over the floor of Long Island Sound to the Housatonic and Connecticut

Rivers, and on the west into the Hudson River. The Hudson River thus becomes a very old, a pre-Silurian, river cutting its way to the ocean in a gorge, perhaps accentuated by falls and rapids, with probably equally picturesque tributaries.

Borings made by the Board of Water Supply of New York City, in connection with the project of bringing water from the Catskill Mountains, have shown the existence of numerous deeply buried channels representing pre-glacial stream courses. Many of them indicate channels cut far below present sea-level at considerable distances back from the Hudson River. From engineering records it appears that the depth to bed rock in the Hudson River has never been determined at any point in its lower course. Profiles of supposed rock-bottom based upon wash-borings have been proven by the recent work to represent simply the bottom of the finer silt filling. The results show that more than 200 feet of more compact material lies below this silt at the point now being tested, and that the rock bottom of the ancient Hudson lies more than 450 feet below the present river level throughout a large part of its lower course. (C. P. Berkey.)

This assumption involves, of course, a much higher elevation of the whole coast. As far as the Hudson River is concerned, the next problem it presents is its historical relation to the *Triassic* beds west of it in New Jersey (Newark formation) and the Palisade escarpment. Geologists agree that the Palisade dike is *intrusive, viz.*, was inserted in overlying beds of sediments, and we must assume a depression for their accumulation in the brackish water (Eastman) trough or basins of the Triassic deposits, which depression, however, *did not* submerge the meridional ridges of Manhattan Island and western Connecticut. Again, elevation supervened, and at this point it seems necessary to intercalate a fault line, perhaps, on the west margin of the Hudson River channel to give differential prominence to the Triassic shales, sandstone, and trap of New Jersey. This escarpment on the Palisades was made more dominant by columnar weathering or disintegration. At the same time and through the long centuries of the Tertiary Age the edge of the continent grew outward by deposition, and even any original Hudson gorge was partially clogged and loaded. (Dr. Spencer's paper reveals precipitous edges to the cañon miles away from Sandy Hook, intimating older and denser rocks than the Mesozoic or Tertiary clays, marls, sands, etc.) Then the Hudson, upon re-elevation of the land, scoured and cut its way out through and beyond these softer accumulations, reasserting the former profundity of its defile.

Cañons of a similar character (Spencer) have been described by Professor Edward Hull, of London, on the east of the Atlantic at the coastal apertures of European or English rivers. The cañon of the Congo River, discovered by Stassano, and the cañon off Cape Verde, described by Mr. Henry Benest, are similar. These submerged river gorges, including those revealed by Dr. Spencer himself in the West Indies and Cuba, all present a coincidence of features so complete as to emphasize a terrestrial identity in origin and history. During glacial times the Hudson River valley, or gorge, disappeared, as a noticeable geographic detail beneath a continental ice-cap.

The East River was a far less imposing phenomenon, probably less ancient. An interesting feature of its bed, as shown by the soundings of engineers, is its hummocky or hilly character, as in the single prominence, on the line of the Subway tunnel to Brooklyn, of rock, and its immediately adjoining fissures or valleys filled with sand and mud. Variable hardness or density of the eroded rock may explain such facts, or again faulting can be conveniently importuned.

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 8th Avenue, but on the east side from 4th 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 débris. 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 crystallizing—or crystallizing under less pressure—fused gneiss, or, in some cases, injected veins. At the same or some subsequent time there may have been intruded through the island gneisses or schists, a series of diorite dikes, igneous eruptives, which were synchronous with a widely distributed motion, disturbance, and plutonic impregnation of the Appalachian continent. Their representation on the island is found in the beds of hornblende rock.

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 escarpment 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 van Kull, the Passaic, swollen by the waters of the Hackensack, united its floods 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 shore, 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. The deep cañons 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 reconstruction 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."

A view of rather amazing import has been advanced by Oswald J. Heinrich, Professor I. C. Russell, and in recent years advocated by Professor William H. Hobbs, which affirms the *union* of the Triassic formation in New Jersey with the same series of rocks in Connecticut, the intermediate zone in New York, now entirely destitute of these beds, having been covered or partially occupied by them. This group of beds has, according to these writers and authorities, been removed by the agencies of denudation. The Triassic areas in New Jersey consist of slates, sandstones (arkose), and conglomerates, with interbedded or transverse dikes of eruptive dolerites (trap-rock), and the same order is representative of this formation in Connecticut. These rocks in the intermediate zone of New York presumably would have had a considerable thickness, and the physical proportions of the process of their complete removal would appear necessarily larger than even the great resource the geologist possesses in long periods of time would competently meet.

Dr. Julien has attempted to reinforce this hypothesis by a rather untenable suggestion. As the minerals known as zeolites, usually associated with decomposing igneous rocks, are found sparingly on Manhattan Island, and as their implantation on unaltered rock suggests the percolation downward of the currents of water charged with them, Julien has presupposed an overlying trap rock (Triassic) from whose decomposition they were derived. This can hardly be maintained. Stilbite (a zeolite) was taken many feet below the bed of the East River, and its origin could scarcely be attributed to the weathering of overlying trap. The occurrences are also too sporadic and individual. And Dr. Julien has himself amplified the evidence for the igneous character of much of the island schist.

Recent study and speculation have, however, developed a geological reconstruction of the rock or land surfaces in the New York area, which has also great interest and receives the endorsement of the United States Geological Survey (New York City, Folio No. 83).

The elevation of the continent proceeded slowly, with possibly intervals or periods of more concentrated and urgent uplift, as at the close of the Lower Silurian day and in Devonian and Carboniferous times; but, always subjected anew to the unwearying processes of weathering and renewal, was again persistently worn down into more even and plane-like surfaces. Over much of this undulating and perhaps monotonous lowland there was laid in Mesozoic times (Jura-Triassic and Cretaceous) a widespread and quite deeply bedded series of sediments, which entered New England up the depressed basin of the Connecticut Valley, but which apparently were absent from the moderately elevated islands or prominences formed by the emergent terranes of the Appalachian highlands, New York Island, the central elevations of Staten Island, and the crystalline ridges in New England. The general tendency and potency of sedimentation were coastwise and southerly. This great plane was slowly raised, and instantly became a broad territory of drainage with a removal of its topographical dissection by streams and rivers. This, it is assumed, occurred in Tertiary times, or those geological ages immediately precedent to the Ice Age, and to it is assigned the final and more significant elevation of the Appalachian Mountains. This problematical plane thus elevated has been called the Schooley plane, "because its flat surface is well represented in the summit of Schooley Mountain, in New Jersey." The softer mineral elements, the more easily transported deposits, were carried away along developing river ways, and, determined by slopes and the nature of their beds, the present river system approached stability. Valleys were formed, and "the process of adjustment and erosion had proceeded so far as to outline the present heights and valleys in their broadest features, when mountain growth was renewed and there occurred the uplift which resulted in mountains of the altitude of the Highlands."

Continuous surficial excavation and differential changes of level brought into topographic eminence the Highlands in New York and New Jersey, Schooley Mountain, the Watchung Mountains, and the Palisades. This hypothetical domelike plane sloped from the Highlands southeastward, and "passed beneath sea-level a short distance south and east of New York City." Manhattan Island, by some rigidity of elevation, continued a meridional ridge upon which *apparently* none of these Mesozoic or Tertiary deposits were placed, although in the Ice Day it was submerged beneath the ice sheet and underwent alternations of vertical position, while upon it remained the transported burden of drift brought to it by the ice. (See "Evidences of Glaciation," p. 189 ff.)

A touch of scenic splendor has been given to this geological retrospection through a proposition of Dr. Julien's. Impressed by what appears to him to be a saturation of the crystalline schists by igneous intrusions, and taking in consideration the widespread evidences of basal dikes, eruptives, and vulcanism along the Atlantic coast in the crystalline areas, he has proposed the imaginative construction of a "coastal chain of volcanoes." Such of these as Julien assumes were located near the cities he has ventured to name. At Wilmington, Delaware, in long past ages he places *Mount Hopokahacking;* at Baltimore, Maryland, *Mount Powhatan;* at Philadelphia, Pennsylvania, *Mount Kuéquenáku;* near Peekskill, on the Hudson, *Mount Sachoes;* at Boston, *Mount Shaumet;* at Montreal, *Mount Hochelaga;* and at New York, *Mount Manhattan.* The distinguished name of their nomenclator must not be allowed to impart too great an objective reality to these phantom peaks.

(Figs. 28, 29, 30, illustrate rock cuttings along the line of the Subway.)

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 min-

Fig. 27. Dolomite beds at 204th Street and Post Avenue.

Fig. 28. Rapid Transit excavation, Broadway, 117th-118th Streets. Cut 25-30 feet deep in Manhattan gneiss. June, 1901.

Fig. 29. Rapid Transit excavation at 145th Street, looking north to 147th Street. October, 1901.

Fig. 30. Looking up Broadway through the Rapid Transit excavation from 155th Street. Heading in rock shown and partially completed arch. May, 1901.

eral species on Manhattan Island is about ninety, and in many cases the specimens have proved of surprising beauty.

L. D. Gale, I. Cozzens, B. B. Chamberlin, D. S. Martin, S. C. H. Bailey, Dr. Feuchtwanger, J. W. Deems, W. E. Hidden, F. Braun, J. F. Kemp, Geo. F. Kunz, Wm. Niven, Ernest Schernikow, Gilman Stanton, Dr. Levison, and F. A. Camp 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 necessary to enumerate all the minerals of Manhattan Island in this article, and I will thus introduce to the public school teachers many which are intrinsically important * and which they may, in their industrious explorations over the island, meet, while the more uncommon may stimulate their curiosity.

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 Avenues, the gneiss quarries at Kip's and Turtle Bay on the East River, from 38th to 44th Streets, a region near 2d Avenue, between 45th and 46th Streets, blocks bounded by 6th and 7th Avenues, from 54th Street to Central Park, are instanced by Chamberlin as important localities, now, of course, obliterated by buildings. The 4th Avenue 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

*An exhaustive catalogue of the minerals of the island up to the date of its publication was prepared by Mr. B. B. Chamberlin (Trans. New York Academy of Sciences, Vol. vii); and his cabinet, together with Mr. Kunz's and the collections of the New York Mineralogical Club, is on exhibition in the Hall of Mineralogy of the American Museum of Natural History.

and Fort George Mr. W. Niven has prospected successfully, adding new species to the island's lists as well as uncovering specimens of unrivaled 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.

Beyond the limits of the island, in the Bronx, the dolomitic beds may repay exploration, while a mineralized fissure in the limestone at the Jerome Avenue reservoir excavations at 205th to 207th Streets offered sphene and actinolite. The regions on the island which should be anxiously watched are those to the west, north of 110th Street, and the itinerant mineralogist with a hammer and an observant eye may meet as unexpected and fortunate a chance as rewarded Dr. Wallace Goold Levison when he found his most interesting chrysoberyls.

Actinolite, the green bladed amphibole, is found as a schist in finely aciculate matted fibres near 221 W. 69th Street (Rev. G. L. Nicholas), also at 78th Street near Amsterdam Avenue, and was taken in West 59th Street at the serpentine area with the "hydrous anthophyllite." A large dike at 128th to 130th Streets, east of Convent Avenue.

Adularia, a form of orthoclase, has been found as small white wedges on a granite, with pink orthoclase, from 55th Street and 6th Avenue. Given by Chamberlin at 90th Street and 4th Avenue, Bellevue, Corlear's Hook.

Albite, the white soda feldspar, was abundant between 3d and 5th Avenues, from 93d to 101st Streets; a crystal in limestone (calcite) in a crevice in rock at 167th Street and Harlem River (Schernikow), with ripidolite; (pericline form) from 101st Street and Lexington Avenue, 104th Street and 5th Avenue, 176th Street and 11th Avenue; (peristerite), glassy with pyroxene, at 109th Street and Amsterdam Avenue; large *pericline* crystals from 38th Street between 5th and Lexington Avenues;

good crystals on hornblende schist at the Speedway and 165th Street.

ALLOPHANE, hydrous aluminum silicate, given by S. C. H. Bailey and Chamberlin as found in "silvery white incrustations."

AMPHIBOLE.—(See Actinolite, Hornblende, Tremolite, Asbestus, Anthophyllite, etc.)

AMETHYST, purple quartz, rare, taken in 59th Street, 6th and 7th Avenues, perhaps from bed of quartz at 117th Street near 4th Avenue.

AMIANTHUS, in serpentine boulders Amity Street, and in West 58th Street; confounded probably with *chrysotile,* which is a fibrous serpentine.

ANALCITE, rare, 101st Street and 5th Avenue, tetragonal trisoctahedrons coating small cavity in hornblende gneiss, with chabazite. It is a hydrous silicate of sodium and aluminum.

ANTHOPHYLLITE (hydrous), tremolite-like, gray-brown, radiating acicular mineral distributed in drift, a changing and hydrous amphibole.

APATITE, the phosphate of calcium, is often found in attractive green crystals, though usually broken in extraction; white crystals are also mentioned by Bailey; developed in granite veins, good dark crystals in quartz, at Fort George, at 120th Street and 5th Avenue; crystals showing hemihedrism from 43d Street and 1st Avenue; not uncommon.

APOPHYLLITE, hydrous silicate of calcium and potassium, drift in trap boulder. (Bailey.)

AQUAMARINE (gem beryl), light green, translucent, from Manhattanville; rare.

ARAGONITE, carbonate of lime, in thin veins, columnar in form, in dolomite from Morrisania, in the Bronx; taken at 4th Avenue and 96th Street.

ASBESTUS, hair-like fibres thinly strewn over or through schist, at 14th Street and 5th Avenue, also in broad sheets of fibres from Spuyten Duyvil (Hall of Geology, American Museum Natural History).

AUTUNITE, hydrous phosphate of uranium and calcium, in scale on quartz in granite, invading the mica sheets, and possibly interleaved with them; yellow.

AZURITE, carbonate of copper, in spots and stains on hornblende schist; oxidized chalcopyrite.

BASANITE, (?) in drift; the touchstone of jewelers; a dark chert.

BERYL, silicate of aluminum and beryllium, not uncommon, but localized; developed in some force at Fort George, and here also replaced in its hexagonal prismatic form by mica, quartz, and feldspar; associated with green mica (muscovite), pink feldspar, and quartz; prism and pyramidal planes in specimens from 190th Street and Amsterdam Avenue; faintly blue, opaque, hexagonal prism from Manhattanville.

BIOTITE, the magnesian iron mica, on the island invariably black, has been found in crystals three inches long at 7th Avenue and 135th Street, and pockets of rich crystal bunches at 56th Street, between 6th and 7th Avenues. It is exhibited in black bundles of plates, curved and impressed. Large masses at 136th to 141st Streets and 7th Avenue.

BORNITE, erubescite, peacock ore, copper and iron sulphide, found veining gneiss with peacock stains, in contact with granite lenses; coloring, by decomposition and oxidation, the mica, quartz, and feldspar a faint grass green, asociated with azurite, which has been formed from it.

BOURNONITE, sulph-antimonide of lead and copper; reported by Hidden.

BYSSOLITE, green moss-like amphibole; reported.

CALCITE, the carbonate of calcium, 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 or gneiss, at 122d Street and Harlem Heights, holds interesting examples in cavities. Calcite is not so common as might be anticipated. Found in the dolomite, and seen with finely papillose sheaves of *stilbite,* scalenohedral, on gneiss at 45th Street and 1st Avenue; elswhere in small crystals; with the ophiocalcite in West 58th Street.

CHABAZITE, hydrous silicate of aluminum, calcium, and sodium; at 43d Street and East River, at 45th Street and 1st to 2d Avenues, rusty brown to gay-brown rhombohedrons; 101st Street and 5th Avenue, brilliant red; 96th Street and 4th Avenue, brown crystals on hornblende gneiss; 95th Street and 4th Avenue, chocolate brown; 44th Street and 2d Avenue, yellow.

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. An agent of the Kingsbury and Turner Water Co. reported laminated massive chalcopyrite (much altered to carbonate) from 108th Street and Columbus Avenue at a depth of 432 feet, associated with quartz.

CHERT, drift.

CHLORITE, silicate of aluminum, iron, and magnesium, rather frequent, in small green scales, 5th Avenue and 104th Street, Manhattan Avenue and 104th Street.

CHROMITE, oxides of chromium and iron, reported in serpentine in octahedral crystals at 60th Street, North River.

CHRYSOBERYL, a mixture of the oxides of aluminum and beryllium, and a rare mineral, has been found by Dr. Wallace Goold Levison in an excavation on the north side of 88th Street "near to and east of Amsterdam Avenue." It was a twin crystal, and was unique, as no other examples of this interesting

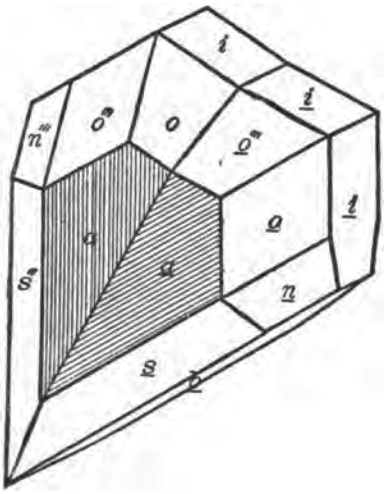


Fig. 31. Crystallographic outline of the twin chrysoberyl found by Dr. Levison.

species had been found on the island. It was found in a "coarse aggregation of smoky quartz, feldspar, and mica."

"The color of the crystal is a light yellowish green, resembling the chrysoberyl of Haddam, Conn. A fragment of an adjacent crystal is more yellow. Its material is quite transparent."

Fig. 32 is an enlargement, by photography, made by Dr. Levison, of this phenomenal find; originally published in his pamphlet. In 1901 Dr. Levison's further investigation was rewarded by finding at 93d Street and Riverside Park a suggestive occurrence of chrysoberyl in six parts, being portions of a large broken crystal, "all somewhat separated and dislocated and buried in quartz," the latter brecciated. The color is a yellow green; it is associated with oligoclase and bright red garnet. Niven and Hidden reported this mineral before Levison's find. Found since by Alfred C. Hawkins and Edgar T. Wherry.

CHRYSOTILE, in serpentine.

CLEAVELANDITE, lamellar albite, reported by Cozzens in boulders at Corlear's Hook.

COCCOLITE, reported (a granular pyroxene usually disseminated in limestone, characteristic of the Adirondacks).

COPPER ALUM (Copper Sulphates), reported by Hidden as "precipitating copper on a knife blade in a weak solution."

COLUMBITE, the niobate and tantalate of iron and manganese, beautiful doubly terminated black crystals in the Kunz collection, from Fort George, associated with beryl.

CRICHTONITE, phase of menaccanite; reported.

DATOLITE, reported in trap; drift.

DOLOMITE, the carbonate of calcium and magnesium, 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. Coarse pink, nodular streaks at Mott Haven. As Chamberlin remarks, good crystals unusual.

DUMORTIERITE, basic, aluminum silicate, sometimes containing boric acid. This mineral is sparingly developed in the United States. It is an unusual mineral anywhere. Formerly, as found on Manhattan Island, it was thought to be a blue tourmaline (*indicolite*). It was first discovered near Beaunan, France. It occurs there in fine grains or needles enclosed in pegmatite, and associated with gneiss. The Harlem specimens were separated from tourmaline by Riggs, and it was supposed to be a new mineral. Later E. S. Dana identified it. It is found also at Clip, Arizona, and in San Diego County, California. W. E. Ford found boric acid in specimens from all three localities, the boric acid in the Harlem specimen being 6.14 per cent.; gravity of the same, 3.211 to 3.302. Found in red granite extending from 123d Street and 4th Avenue to Madison Avenue and 116th Street; usually in thread-like bunches penetrating orthoclase or oligoclase, rarely in quartz or mica.

EPIDOTE, a silicate of aluminum, iron, and calcium, 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 Dr. Kunz from Columbus Avenue.

Very good specimens have been taken from the region about

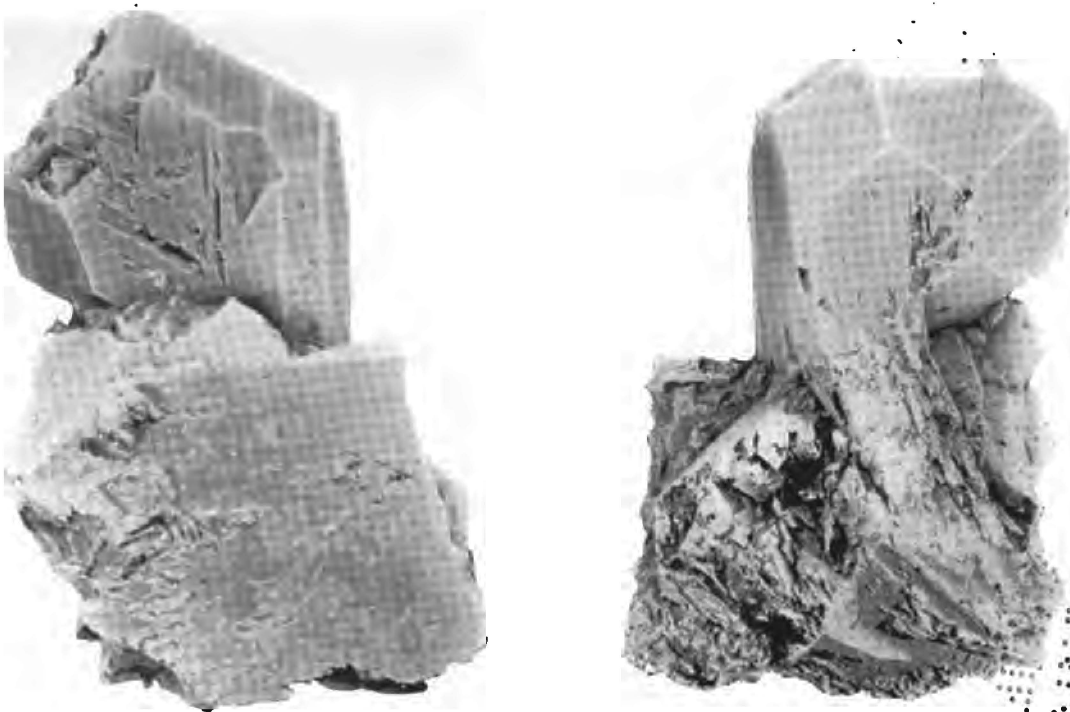


Fig. 32. A Twin Crystal of Chrysoberyl enlarged about 4½ diameters. From the Borough of Manhattan, New York.

Fig. 33. Garnets from 65th Street and Boulevard, found by Mr. G. S. Stanton.

Fig. 34. The large Tourmaline found by Mr. Wm. Niven.

West 56th and 57th Streets, near 6th and 7th Avenues. Found streaking the hornblende rocks.

ESSONITE, light colored garnet, attractively set in white feldspar and glistening silvery mica, at Fort George.

FIBROLITE, silicate of aluminum, in white-gray fibres at Fort George, Washington Heights, 52d Street and Madison Avenue.

FLUORITE, fluoride of calcium noted by Hidden, "in yellow and blue cubes 1-4 inch in diameter, on gneiss at Hell Gate." H. S. Williams found a large (six inches by three) greenish block of fluorite, with rusty brown separations, between 53d and 54th Streets on Broadway in the Subway. This region has been prolific of mineral treasures. This fluorite is exhibited in collection of New York Mineralogical Club. Rare.

FLUOCERITE, a fluoride of rare bases, cerium, didymium, lanthanum, yttrium, erbium; very rare; one specimen reported by Hidden.

GALENITE, sulphide of lead, cubic crystals from 43d Street and East River, from Aqueduct Shaft No. 27; crystals on stilbite (F. A. Camp) from Harlem at Convent Avenue; unusual, also with chabazite, 92d and 96th Streets, and 4th Avenue.

GARNET, a variable silicate containing, on Manhattan Island, usually aluminum, iron, magnesium, and calcium. Garnets are plentiful throughout the island rock, dense concretions of them (the so-called seed garnet) of a pale red color, associated with apatite, having been taken from a vein in 83d Street and Amsterdam Avenue, while inserted over the faces of orthoclase in a cross-cut granite vein at 65th Street garnets (Fig. 33) with modified dodecahedral faces of deep brown were found in 1888. Dr. Kunz has an enormous specimen, weighing nine pounds ten ounces, of a dull brown, now exhibited in the collection of the New York Mineralogical Club at the Museum of Natural History. In many localties, especially in granite seams, this familiar mineral is encountered.

Mr. Chamberlin remarks that from Lenox Avenue and 119th Street "eastward and northward to Mount Morris Park, 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.

In the Chamberlin collection is a gem-like crystal of garnet, dense in places, penetrated by a crystal (prism) of black tourmaline passing like a blade through its exact center. Mr. Niven secured some excellent large crystals northward and west. Dodecahedral garnets seem uncommon on the island. Drift arkose from New Jersey sometimes contains garnets of a simple type, greenish or black.

GRAPHITE.—Mr. F. A. Camp reports this somewhat unusual mineral from 152d Street west of 7th Avenue. Robinson and Bailey have both found it.

GYPSUM, found in the Chamberlin collection as a net-work of white crystals on gneiss.

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 calcium or barium and aluminum, 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 4th Avenue improvement, where the tracks of the Central, Hudson River Railroad, Harlem and Hartford Railroads were first sunk below grade.

In mentioning them Mr. Chamberlin, who himself first announced harmotome, 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 4th Avenue to 102d Street near Lexington Avenue. 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 Street between 1st and 2d Avenues, a second prolific locality afforded plates of stilbite two feet square."

HARMOTOME, hydrous silicate of aluminum, barium, and potassium, in very pretty crystallizations of interpenetrating cruciform twins, discovered by Mr Chamberlin on surfaces of gneiss and associated with chabazite and stilbite; of two colors, dark brown and yellow. It is a hydrated silicate of aluminum, barium, and potassium. It is also found as flesh-red crystals of considerable size in strings, through seams in gneiss at 92d Street.

HEULANDITE, a hydrated silicate of aluminum and calcium, found in faintly colored straw-yellow crystals, lamellar, pearly, deepening in tint to reddish yellow.

HYDRODOLOMITE, a somewhat nondescript mineral, probably a hydrous carbonate of calcium and magnesium, reported.

HYPERSTHENE, a ferro-magnesian silicate in the pyroxene group; reported from builders. Improbable; the material seen is broad-bladed hornblende, which does occur in the Palisade dolerite.

IDOCRASE (Vesuvianite), reported, improbable. It is a basic calcium aluminum silicate.

IOLITE, a silicate of aluminum, iron, and magnesium, found by Niven, identified by Hidden, from 170th Street and Amsterdam Avenue (Fort George); gray-green, green-blue in color; polished fragment in the Kunz collection. Rare.

JASPER, form of quartz, massive, opaque, in pebbles in drift; reported along Harlem River.

JEFFERISITE, a micaceous mineral very much hydrated, a silicate of aluminum, iron, and magnesium, when highly heated swelling, exfoliating, and becoming white and opaque. Uncommon; found at 100th Street and Fifth and Third Avenues, marked as coming from cavities in gneiss, also in polyhedral surfaces, perhaps coating interior minerals.

KAOLIN, KAOLINITE, clay, decomposition of feldspar; a good example from 56 feet below curb at 12 and 14 West 32d Street (A. S. Coffin, C. E.) is in the Mineralogical Club collection.

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 3d and Lexington Avenues. It also forms a local schist and has been so regarded. "Between the blades of kyanite appeared a deep-hued smoky quartz, also garnets and scapolite." Camp observed it on Convent Avenue at 128th to 130th Streets.

LAUMONTITE, a hydrated silicate of aluminum and calcium; reported, rare.

LIMONITE, hydrated sesquioxide of iron, bog-ore, common on low-grounds; "in globular forms resembling shot. 55th Street, 6th and 7th Avenues, and elsewhere" (Chamberlin).

MAGNETITE, proto-sesquioxide of iron, in solid cubical black blocks, 170th Street and Eleventh Avenue; "crystallized in lamellar and radiated forms, between leaves of muscovite (the magnetic markings), Riverside Park and elsewhere" (Chamberlin); found also in veins of quartz.

MALACOLITE, a white pyroxene, quite frequently found in the dolomite (Kingsbridge limestone), and sometimes stoutly developed in thick-bent and fractured crystals (E. C. Eckel): usually flat, yellowish-white, crumbling prisms.

MALACHITE, green carbonate of copper, stains, blotches, and colorings, in gneiss and granite, from oxydized chalcopyrite or bornite.

MANGANESE OXIDES (WAD, Bog-manganese, *Psilomelane*, etc.). Mr. Yeshilian has taken some pains to examine black, burnt-looking exposures of the schist, especially on Washington Heights at 146th Street, between Broadway and Amsterdam Avenue. These he found to be unquestionably accumulations and crusts of manganese oxides. He reports finding a deposit of it about 20 feet square and one foot deep on the site of the new Orphan Asylum between Amsterdam and Convent Avenues. He remarks it is not far from the hornblende schist in its vicinity.

MARCASITE, sulphide of iron, reported from excavations for addition to Metropolitan Museum of Art, "in reniform and globular masses" (Chamberlin).

MARMOLITE, a slickensided and indurated serpentine, 63d Street and 11th Avenue.

MENACCANITE, the oxide of iron and titanium, is found in flat black plates of considerable size in granite and on gneiss. The form hystatite (washingtonite), with a low percentage (15-16) of titanium, is probably found in thick plates, and may include nearly all the ilmenite on the island.

MICROLITE, an isometric calcium tantalate containing also, with fluorine, a cluster of rare bases: "small octahedrons in oligoclase, 39th Street, 6th and 7th Avenues" (Hidden).

MOLYBDENITE, the sulphide of molybdenum, a graphite-looking mineral, is found in excavations in flat plates or crystals, on gneiss, and quartz in veins. Mr. F. A. Camp reports that molybdenite was seen in several veins (20 to 30) in the amphibolite dike east of Convent Avenue in "fine clear sheets"; the veins were made up of quartz, orthoclase, and garnets.

Molybdite, yellow oxide of molybdenum, formed from the molybdenite; not common.

Monazite, phosphate of cerium, lanthanum, and didymium, frequently with thorium. Found by Niven and Hidden in perfect doubly terminated monoclinic prisms from 155th Street and Amsterdam Avenue, garnet brown. Unusual, but quite plentiful locally.

Mountain Cork, a fibrous, asbestus-like, pliable white felted amphibole. Reported in boulders, Amity Street.

Muscovite, the common white to brown mica, silicate of aluminum and potassium, 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.

In the Kunz collection large crystals, roughened exteriorly, are from Fort George. Chamberlin thus characterizes its varieties and localities:

"In large hexagonal crystals, twelve or fifteen inches in length. Found in excavating site for car-stables, 6th Avenue and 45th Street.

Good crystals, one nearly the size of the above, 10th Avenue and 130th Street.

Finely shaped crystals, 56th Street, 6th and 7th Avenues; 45th Street and 2d Avenue; 43d Street, 2d and 3d Avenues.

Also in dolomite at junction with gneiss, Brook Avenue and 145th Street.

Good crystals, Riverside Park.

Masses of small crystals, 63d Street and Broadway.

"*Spear Mica,*" 43d Street, 2d and 3d Avenues.

Prismatic, do.

"*Picture*" mica, excellent specimens, some 12 inches in length, Riverside Drive and 120th Street.

Striped and banded, parallel to sides of crystals, in some cases a rich blue (S. C. H. Bailey), 45th Street and 2d Avenue; 40th Street, 2d and 3d Avenues, and various localities.

White or silvery (perhaps sericite or a similar variety), 96th Street and 3d Avenue; 101st Street and Lexington Avenue; 126th Street and St. Nicholas Avenue.

Green, 93d Street and 9th Avenue; 101st Street and Lexington Avenue; Convent Grounds, 8th Avenue and 128th Street; Fort George, and elsewhere.

Golden-yellow, in small leaves, in a very white oligoclase, found in paving-material, Boulevard at 63d Street."

NATROLITE, hydrated silicate of aluminum and sodium, "in delicate, snow-white globes of radiated, acicular crystals. Associated with chlorite, sphene, and rutile at the brown calcite locality. Fifth Avenue and 104th Street" (Chamberlin).

NECRONITE, a fetid feldspar, originally found in limestone near Baltimore; taken on Manhattan Island, "of a bluish white color in tabular masses in limestone at Kingsbridge" (Chamberlin).

OLIGOCLASE, a feldspar, a silicate of aluminum, calcium, and sodium; generally greenish, and under magnification showing repeated striae (twinning) like ruled lines. Common; crystallized in well-developed crystals at 147th Street and Amsterdam Avenue, in solid quartz. Large crystals from 134th Street and Amsterdam Avenue, and on Broadway (F. A. Camp).

ORTHITE, a silicate of rare bases, the cerium and yttrium metals; usually applied to the thin, straight, or curved crystals, a variety which readily undergoes alteration. The crystals on Manhattan are dark, reddish brown to black, frequently bent, and have been taken in oligoclase granite at 56th Street and Broadway, from two and a half to three inches in length, and looking like thin rusty nails in the rock.

ORTHOCLASE, silicate of potassium and aluminum, 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.

Chamberlin has remarked of its occurrence on Manhattan Island: "Conspicuous masses are not so common, and the collector needs to avail himself of good opportunities for securing fine specimens of either the laminated plates or crystallized fragments. The feldspar varies in color from a dull white through different shades of yellow and flesh-color to a bright red. Some of the localities were the following:

In broad flesh-colored plates with highly lustrous surfaces, 96th Street and 4th Avenue; 56th Street, 6th and 7th Avenues.

Brownish gray variety resembling perthite, 43d Street, 2d and 3d Avenues.

Red, 4th Avenue and 120th Street.

Cream-colored, 46th Street and 2d Avenue.

White, 94th Street and 3d Avenue.

White, slightly opaline, Harlem Tunnel.

Crystals are usually of the primitive rhombic form found lining fissures in gneiss.

Good examples were obtained at 96th Street and 4th Avenue, 56th Street and 6th and 7th Avenues, and Lexington Avenue and 44th Street.

More highly modified forms and larger in size usually appear in granite veins. A few handsome specimens (in collection of Geo. F. Kunz), among which was a remarkable twinned crystal, were found at Fort George; also at 43d Street and 1st Avenue. At the latter locality the feldspar of the granite vein was changing to kaolin. The mica and beryls present partook of the change. The orthoclase crystals were of large size, some six by four inches. Crystals of less size appear in a porphyritic rock on the east bank of the Harlem River above McComb's bridge (L. Winslow).

Remarkably fine groups of modified crystals coated with albite (G. J. Brush) were secured at 96th Street near 3d Avenue."

PHACOLITE, variety of chabazite, distinguished by flatness or psuedo-hexagonal form from twinning. Very rare. Reported from 43d Street and East River.

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.

PINITE, from iolite, by alteration, through hydration and solution.

PYRALLOLITE, under pyroxene; an alteration product; occurs in Finland in limestone; reported from the dolomite at Kingsbridge.

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.

At 1st Avenue and Kipp's Bay (Schernikow) pyritohedrons almost rounded by channeled flutings (oscillation with cube), At 32d Street between 5th and 6th Avenues, at a depth of forty-nine feet (A. S. Coffin), quartzite was taken out coated with pyrite.

PYROXENE, a mineral in composition allied to hornblende, but in the examples found on the island quite often 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.

Green crystals occur, as at 56th Street, 6th and 7th Avenues, but they are very rare.

PYRRHOTITE, magnetic sulphide of iron, in imbedded nests from the dolomite at the Kingsbridge Ship Canal.

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

Terminated crystals with crystallized oligoclase from 56th Street and Broadway, smoky from Fort George, milky from 118th Street and Morningside Drive, projecting crystals on granite at 181st Street and Harlem River, may be mentioned. Under the building of the Title Guarantee and Trust Co. at 146 Broadway, at a depth of 175 feet, *gold* quartz was reported.

RIPIDOLITE (Clinochlore), a mineral of the chlorite family, a hydrous silicate of aluminum, iron, and magnesium, is developed extensively in Westchester County, and appears on Manhattan Island. From the Jerome Avenue quarry, in green-blue plates; in green plated rosettes in quartz from 104th, 105th Streets, and 5th Avenue; taken forty-four feet below curb at 12, 14 West 32d Street. (A. S. Coffin.)

RUTILE, oxide of titanium, not uncommon, saturates phlogopite in microscopic form, and occurs in good crystals; channeled square prisms with scapolite and prochlorite from Fort George; large crystals in the Bronx on Jerome Avenue at 171st Street. Exquisite small crystals, splendent and blood-red on edges in transmitted light. Occurs in association with quartz, feldspar, and mica.

SCAPOLITE (Wernerite), silicate of aluminum, calcium, and sodium; in square, yellowish prisms, also massive, frequently in gray quartz. Taken at Fort George, 155th Street and Amsterdam Avenue, 100th Street and Lexington Avenue, and at 120th Street and 4th Avenue.

SERICITE, a fine scaled muscovite, light in color, from 96th Street and 3d Avenue.

SERPENTINE, the hydrous silicate of magnesium, in drift and in place; from the 10th Avenue hills and in dolomite. Serpentine in boulders occurred in foundations in Exchange Place.

SIDERITE, carbonate of iron, found as sphero-siderite, quite commonly. With stilbite in brown, dark spheres, in pea-form clusters on gneiss. Localities at 90th Street and 4th Avenue, 45th Street and 1st Avenue, 70th Street and 4th Avenue, 82d Street and 4th Avenue.

SPHALERITE, sulphide of zinc, amorphous and in isolated measurable crystals in dolomite, of dark honey-brown color.

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. At the Jerome Avenue quarry the brown, flat, roof-shaped crystals are common; but the green-yellow forms, suggestive of Tilly Foster crystals, at Fort George and at 190th Street and Amsterdam Avenue, are pre-eminent.

STAUROLITE, silicate of aluminum, iron and magnesium, reported.

STILBITE, silicate of aluminum, calcium and sodium, with water; of superb character, light stucco brown or yellow to chocolate tints and not infrequently white, immensely developed at the dike, 128th to 130th Street, east of Convent Avenue. Good specimens from Subway tunnel at Battery, 60 feet below surface of rock. (Boniface and Atkins.)

TALC (Soapstone), hydrous silicate of magnesium, here and there as scales.

TELLURIUM (Graphic), reported.

THOMSONITE (a zeolite), hydrous silicate of aluminum, calcium, and sodium; reported.

TOPAZOLITE, a light yellow garnet; reported.

TORBERNITE, phosphate of uranium and copper, in green square tables, uncommon.

TOURMALINE, silicate of aluminum, iron, magnesium, 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. 34) Fort Washington Avenue, while radiating 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.

Mr. Chamberlin uncovered the really remarkable deposit of iron (black) tourmaline, "in a vein of gray quartz traversing gneiss, parallel to the stilbite veins near the Fourth Avenue tunnel, above 96th Street." These crystals were of high grade, terminated and brilliant. Tourmaline in places becomes a rock ingredient and forms a gneiss.

TRIPHYLITE, phosphate of lithium, iron, and manganese; reported.

TREMOLITE, white-bladed or needle-formed amphibole; at the 10th Avenue serpentine locality; in dolomite.

URANINITE, oxides of uranium, with lead, thorium, etc.; reported.

VERMICULITE, near jefferisite, a hydrous, micaceous mineral spurting out, when heated, worm-like ribbons; reported.

VIVIANITE, phosphate of iron, dichroic and usually, to the eye, blue; reported.

WAD, see manganese oxides.

WASHINGTONITE, see menaccanite.

WATER, chalybeate (iron) waters reported; many wells have been sunk on the island; one reported to the author sunk 432 feet yielded 1,200 to 1,500 barrels a day, two others driven to depths of 1,001 and 1,500 feet yielded nothing.

WOLLASTONITE, *silicate of lime;* reported.

XENOTIME, MONAZITE, AND ZIRCON, the first two phosphates of rare earths (Cerium, yttrium, erbium, lanthanum, didymium), and the last silicate of zirconium, 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 clusters 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 aluminum known under the name *dumortierite.*

This mineral was at first regarded as *kyanite* and later referred to hornblende, rhætizite, and tourmaline. It is of a beautiful blue, and in strict prismatic examples verges into grayish 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 becomes more and more clear, fixed, and definite.

In addition to the above list, *Spinel,* the oxide of aluminum with the oxide of magnesium, can be seen in dark octahedrons in the Kunz collection from 111th Street and Madison Avenue. Also *Prehnite,* a green hydrous silicate of aluminum and calcium, in little spheres, has been taken by Mr. D. J. Atkins from the Subway tunnel under the East River.

Fifteen years or more ago the approach to the lawn and grounds of the Convent of the Sacred Heart in Harlem led up a gradually inclined path or road, reached through a gateway entrance near the present 126th Street, and the visitor was there impressed by the vertical wall of rock in its vicinity. This wall was a section of the hillside itself. The opening of Convent and St. Nicholas Avenues and the cross streets from 126th to 130th Streets has obliterated, by blasting and removal, this conspicuous landmark. The process of reduction uncovered a most interesting thick seam of actinolitic schistose rock, which rose vertically and dike-like between the gneissic beds, whose structure in its neighborhood seems to have been preponderatingly feldspathic and quartzose. Fig. 35 shows the stump of this actinolitic interlineation. The rock is a densely felted mass of short actinolite fibers or strips varying from a typical green to a gray-white, like tremolite, and showing the kneaded and crowded centers of radiation of the transversely fractured needles. The rock is hydrated, scarcely feldspathic, and appears in dark patches hornblendic. The more bleached fragments resemble strongly the boulders of anthophyllite encountered superficially over the island. Of the former extension of this bed or dike, Mr. F. A. Camp, who has collected its mineral contents and associations, says:

"The actinolite dike, before blasting operations were commenced, projected from the surrounding rock to the extent of 6 to 8 feet for about 80 feet from the north side of 129th Street. The general direction was toward N. N. E. The projections were about 3 feet in width, increasing as they went down. A large amount had been broken off from these projections, as was apparent from the actinolite boulders, down

Fig. 35. Actinolite dike at 128th Street and Convent Avenue, Manhattan Island.

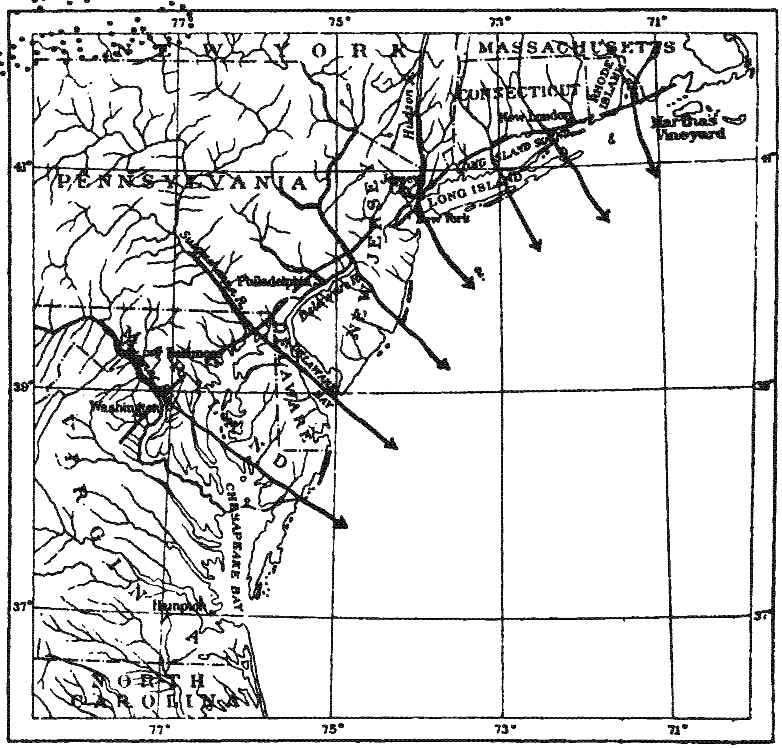


Fig. 36. Primitive drainage lines of rivers.

to the friable dust, which was removed with pick and shovel. For 20 feet to the west the surface was covered with the green actinolite dust and fragments up to large boulders. I should say the gneiss walls were about 4 feet apart at 128th Street, 15 feet apart at 100 feet north, where the stump now appears. Above the present stump no solid rock appeared on the surface, but what appeared to be a deep, green clay. On the removal of this clay the actinolite was struck. My attention was called to this dike almost every time I asked the men operating whether they had found anything new. They all said it was the toughest rock they ever had dealings with. A similar greenish soil containing actinolite continued from the 129th Street end of the dike to the N. E. corner of 128th Street and Convent Avenue, but I did not see solid actinolite in place. It may have been that the actinolite was washed down from the dike into the depression in the gneiss rock, or it may have been that the depression was caused by the decaying of the dike in place. The gneiss to the east of the depression was 10 to 15 feet higher than the gneiss to the west of the depression."

East of the degraded dike there were broad surfaces (20 feet square), rusty brown, through iron staining, showing gneissoidal partings, which must have been more extensive, and indicated a possibility of slipping of the steeply inclined foliæ.

BIBLIOGRAPHY

In 1816, Hayden, in the Geological portion of Professor 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 New York, 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 predominate 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, Professor 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 New York, 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.

Professor 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.

Professor 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 1878, Professor Israel C. Russell read his paper on "The Physical History of the Triassic Formation in New Jersey and the Connecticut Valley" before the New York Academy of Science, in which he claimed "that the red sandstones and shales of New Jersey and of the Connecticut Valley are the marginal portions of one great Triassic estuary deposit," and that they came together over the New York area now lying between them, quite free of any member of the formation.

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

In 1885, A. Lindenkohl, "Geology of the Sea-Bottom in the Approaches to New York Bay," American Journal of Science, Third Series, Vol. 29, p. 475, describes submerged channel of the Hudson River over the Coastal Plane.

In 1887, Professor 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."

In 1890, Professor F. I. H. Merrill discussed, in the American Journal of Science, the "Metamorphic Strata of Southeastern 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 New York State Museum Report of that year.

In 1895, Professor J. F. Kemp read before the New York Academy of Sciences a short paper, entitled "The Geological Section of the East River at 70th Street, New York," which was important as offering partial proof that the bed of the East River was cut in dolomite rock.

In the February number (1899) of the American Geologist, Mr. E. C. Eckel published his article on "Intrusives in the Inwood Limestone of Manhattan Island."

In 1900, Professor A. A. Julien read before the New York Academy of Sciences a paper, entitled "Notes on the Origin of the Pegmatites from Manhattan Island," an epitome of which can be found in Science, Vol. xii (1900), p. 1006.

In 1901, Dr. Wallace Goold Levison published his descriptive pamphlet, "Crystals of Chrysoberyl From the Borough of Manhattan," with figures (enlarged from the original by photography). This comprised two finds.

In 1901, D. H. Newland, "The Serpentines of Manhattan Island and Vicinity and Their Accompanying Minerals," urges the eruptive origin of the Staten Island serpentine. School of Mines Quarterly, Vol. xxii, pp. 307 *et seq.*

In 1902, Professor William H. Hobbs read before the New York Academy of Sciences his paper, "The Geology of the River Channels in the Vicinity of New York," in which he contended that Manhattan Island is an orographic block outlined by faults or rectilinear displacements. (See Science, for Dec. 5, 1902, Vol, xvi, No. 414.)

In 1902, Professor William H. Hobbs published in the Bulletin of the Geological Society of America (Vol. xiii, pp. 139-148) a paper on "Former Extent of the Newark System," in which he returned to a redevelopment and enforcement of Professor Russell's view that the Triassic beds of New Jersey and Connecticut were continuous, and extended over the New York Island area, and have been removed by denudation.

1902. There appeared in this year the magnificent folio atlas, No. 83, of the United States Geological Survey, embracing the New York City, Paterson, Harlem, Staten Island, and Brooklyn Quadrangles, with thirteen folio maps, two sheets of illustrations, and the following important text contributions:

1.—General Geography of the District. Richard E. Dodge, Bailey Willis.
2.—Geology of the District. Bailey Willis, F. I. H. Merrill, N. H. Darton, Arthur Hollick, R. D. Salisbury.
  (1)—Metamorphic Crystalline Rocks. Frederick I. H. Merrill.
  (2)—Later Paleozoic Conditions. Bailey Willis.
  (3)—Juratrias Rocks. N. H. Darton.
  (4)—Later Juratrias and Early Cretaceous Events. Bailey Willis.
  (5)—Cretaceous Deposits of Staten Island. Arthur Hollick.
  (6)—Events of Later Cretaceous, Eocene and Neocene Times, Bailey Willis.
  (7)—Pleistocene Formations. Rollin D. Salisbury.
3.—Physiographic Features of the District. Bailey Willis, R. E. Dodge.
4.—Water Supply of New York City. Henry A. Pressey.

In 1903, Professor William H. Hobbs published his "Tectonic Geography of Southwest New England and Southeast New York" (Bulletin of the Geological Society of America, Vol, xv). In this paper he develops his now well-known views on origination of topographic features through faults and displacement.

In 1904, Professor William H. Hobbs, on "Lineaments of the Atlantic Border Region" (Bulletin Geological Society of America, Vol. xv, p. 483).

In 1904, Professor A. A. Julien published his elaborate paper, "Genesis of the Amphibole Schists and Serpentines of Manhattan Island, New York," in the Bulletin of the Geological Society of America, Vol. xiv, pp. 421-494, pls. 60-63.

In 1905, Professor William H. Hobbs published his "The Configuration of the Rock Floor of Greater New York" (Bulletin United States Geological Survey, No. 270). In this pamphlet the author collected the observations of rock soundings made in New York City.

In 1905, Professor William H. Hobbs published his "Origin of the Channels Surrounding Manhattan Island, N. Y." (Bulletin Geological Society of America, Vol. xvi, pp. 151-182); contains useful line sketches of sections.

In 1905, Dr. J. W. Spencer published his "Submarine Cañon of the Hudson" in the American Journal of Sciences (4th Series, Vol. xix, p. 1), amending Lindenkohl's survey.

In 1905, Professor Lewis M. Haupt, "New York Harbor and its Improvement," American Association of Advanced Science. Title only found in published volume of the Association.

In 1905, W. T. Schaller, in "Contributions to Mineralogy" (Bulletin United States Geological Survey, No. 262, p. 94), describes *Dumortierite* from Manhattan Island.

In 1906, Dr. A. A. Julien published his "The Occlusion of Igneous Rock Within Metamorphic Schists as Illustrated On and Near Manhattan Island, New York," in which he describes the belt of hornblende gneiss at Spuyten Duyvil.

In 1907, "Physiography of the Lower Hudson Valley," Professor J. F. Kemp (Bulletin Geological Society of America, May, 1907).

In 1907, "Limestones of Westchester and Putnam Counties, New York," Professor Charles P. Berkey; a study of the variations and comparisons of the relationships of the formations characteristic of the Highlands region of New York.

In 1907, "Structural and Stratigraphic Features of the Basal Gneisses of the Highlands," Professor Charles P. Berkey. An epitomized statement of very considerably extended and detailed field-work. The author defines a basal central *massif* of variously composed gneisses much dissected by faults and injected with granites, diorites, and gabbros, and this pre-eminently concentrated in the Highlands. Over the basal gneiss he formulates two groups of formations—a northern—phyllite or slate (*"Hudson River"*), fine-grained blue and white banded limestone (*"Wappinger"*), a fine-grained quartzite (*Poughquag, not Lowerre*)—and a southern—coarsely crystalline mica schist, pegmatitic (*Manhattan*), crystalline limestone (*Inwood*), a quartzite (*Lowerre*)—*These two groups are nowhere in contact with each other.* The southern (forming New York Island, etc.) conforms well with the basal gneiss, and is *pre-Cambrian.* The Lowerre quartzite is a phase of the Fordham gneiss simply.

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 cobblestones, tell the singular story which the long, tireless, and infinite retinue of *glacialists* has 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 our 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. And recent borings for water, conducted by the Arbuckle Brothers at Jay Street and in the block bounded by Pearl, John, Plymouth, and Adams Streets, have still further conclusively shown this. Over 2,000 feet of solid rock was penetrated in this unavailing search, which resulted in an impoverished supply of saline water. It has further been demonstrated that generally under Long Island this supporting arch is reached at varying depths: at Woodside, for instance, the rock is 500 feet below the surface, at Greenport it is 650 feet deep, and at the northern point of Great Neck 325 feet, and on the west from Bay Ridge to Bath Beach it is 200, 300, 400, 500 feet, progressively.

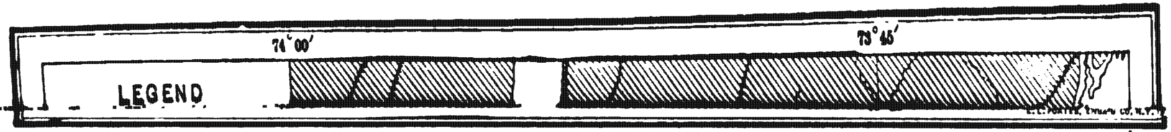
The entire superstructure of the land over these basal beds is not, however, entirely drift. Conclusions previously held by inference have in late years rapidly culminated into proof that a widely extended group of clay beds referable to the Cretaceous, and possibly Tertiary formations, underlies Brooklyn 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. These latter are reviewed in the following section on glacial geology.

As long ago as 1838 Mather, of the New York State Survey, observed the resemblance of clay beds on the north of Long Island to the clays of the Raritan beds of New Jersey, and this caused him tentatively to assign to both a geological equivalence. And now this cretaceous sheet has been traced eastward into Martha's Vineyard, and our imagination is permitted to reinvest this coastal area with tropical vegetation at that long distant day. This topic of the geology of Long Island solicits introduction at this point in this book, and sensibly becomes urgent by reason of inquiries by school-teachers as to this very subject. It has also secured an authoritative presentation in the Professional Paper, No. 44, of the United States Geological Survey. (Veatch, Slichter, Bowman, Crosby, and Horton.)

Long Island is a fusi-form strip of land 120 miles long and 23 miles wide at its widest point, and split at its eastern end into two lobes, to which whalers have expressively applied the names of North Fluke and South Fluke, from the suggestion of a whale's tail. Its higher elevations are on the north, in an irregular line of hills which attain a height of 420 feet at High Hill, and which cross Brooklyn and terminate at the Narrows. This range of hills divides eastward and projects two ribs into the north and south arms of land inclosing Peconic Bay, while, approaching the southern limit of Long Island Sound, its declivities plunge sometimes steeply into that body of water, and its outlines are deranged by picturesque and deeply emphasized indentations. South of this northern marginal rim the island presents a sloping plain to the ocean, which inundates its southern shores, forming many embayments, beyond which a thin reef of sand makes a slender fence against the outer sea and creates a chain of semi-inland bays: Jamaica, Hempstead, Great South, Moriches, Shinnecok.

The basal, hard, crystalline rocks underlying the island have been alluded to. Immediately above these it is believed that the Cretaceous beds lie, and while some of them form visible topographic features, they are for the most part buried, and their position and succession is determined by wells. The hidden sources of water supply which Long Island is now seeking are to be found, in part, in the Cretaceous sands. The beds of the Cretaceous are described as consisting of strata, of a depth of 300 to 400 feet, of sand and plastic clays, often brightly colored, resting on the crystallines. These pass upward into light-colored quartz sands, with occasional clay beds, on the north, and into fine gray lignite-bearing sands and clays on the south shore. The greensand marls of New Jersey, with their marine fossils (the teachers may see these latter abundantly displayed in the fossil-shell layer at Atlantic Highlands, N. J.), are absent in the Long Island Cretaceous, but plant remains are present, indicating shoal water or near-shore conditions. The Cretaceous gravels are

MAP II



MAP SHOWING DATA BEARING ON THE POSITION OF BED ROCK IN WESTERN LONG ISLAND, NEW YORK, AND VICINITY.

By A. C. Veatch.

1904.

Scale

5 0 5 10 miles

characterized by Veatch as "composed of quartz or locally derived quartz-conglomerate, with occasional very much decomposed milk-white chert fragments."

In the investigation conducted by Veatch, a datum plane of extreme value was determined. It was a water-bearing sand 150 to 200 feet above bed-rock in 14 north shore wells, having a southeastward dip, while "a continuation of the lines of equal depth parallel to the line of strike showed that not only the non-water-bearing gravels of the Woodhaven well and the good water carriers of the Barren Island wells belonged to the same horizon, but also, the water-bearing beds in certain wells in New Jersey, which encounter a gravel horizon at a somewhat similar height above bed-rock." This is called the Lloyd sand. This is supposed to have an extreme dip of 80 feet per mile, but this would not appear uniform. It underlies Brooklyn, in part. The most important outcrop of Cretaceous on Long Island is in the West Hills on the road leading from Melville to Hicksville, where there is a succession of (from *top* to *bottom*):

1.—Dark colored, lavender, green, black sandy clay.
2.—Finely laminated red clayey sand.
3.—Finely laminated green, white, and pink clayey sand.
4—Ferruginous sandstones.
5—Yellow sand with ferruginous plates.
6.—Irregularly bedded gray clayey sand, blotched.
7.—Covered.
8.—White clayey sand with large quartz gravel.
9.—Covered.
10.—Stratified orange-colored sandy clay, ferruginous plates.
11.—Very black sand and gravel, stained, manganese.
12.—Coarse white sand and yellow clayey sand.

The evidence gathered thus far points to the absence on Long Island of the 250 to 450 feet thick phosphatic marls and greensands of New Jersey. In New Jersey the succession is Raritan plastic clays, Matawan sands and clays, the marls at the top. The Lloyd water-bearing sand continues from

Long Island to New Jersey, and the Long Island beds generally are related to the older (Raritan, Amboy) beds of New Jersey, but the lignite-bearing sands on the south merge into the formation next above, *viz.*, the Matawan. This Cretaceous zone is a narrow strip, striking northeast and southwest, crossed from New Jersey to Long Island.

Outcrops that have become famous and have yielded plant remains are at Glen Cove, Cold Spring, Great Neck, Lloyd Neck, and Sea Cliff. Cretaceous fossils have been found in the drift in Brooklyn, at Flushing (Cemetery), but their origin is, of course, problematical. The Cretaceous beds have been folded and disturbed, and this vitiates conclusions, so far as they are guided by depths. It would seem that if the marine marls and greensands of Monmouth County, New Jersey, are Upper Cretaceous, Long Island Cretaceous, in which they are absent, is Lower Cretaceous, and did not experience during its Cretaceous history as deep a submergence as the southern areas now included in New Jersey.

Succeeding the Cretaceous the Tertiary deposits should be expected, but on Long Island, however naturally it might be regarded as an areal prolongation of New Jersey, and geologically assimilable to New Jersey, these deposits are not represented very unmistakably. Of course, they may have largely been removed by erosion, or Long Island may have been withdrawn, through elevation, northward from the arena of Tertiary sedimentation.

At this stage of his study of the development of Long Island topography, Mr. Veatch unfolds a scheme of reconstruction by which, through erosion, at higher levels than at present, a hill and valley system was wrought out. This had a continental significance. It was represented in Long Island, in New Jersey, in Delaware, in Maryland, and had, it is assumed, something to do with the final and recent courses of the Connecticut, Delaware, and Potomac Rivers. The succession of events, as pictured, was like this: The early Pliocene (Tertiary) was an erosion interval; the softer Cretaceous beds were removed; the harder, more resistant, remained. These latter began the establishment of a hill series through New Jersey (Perrineville, Monmouth County), with an accompanying valley, the Hightstown Valley, and extending northeasterly in Long Island in the Mannetto Hills, and its reciprocal depression, Long Island Sound—or valley. The rivers issuing from the higher inland country traversed the valleys and the hills, through the transverse depressions, and reached the ocean almost in a direct line (Fig. 36). Then followed a later pliocene (Lafayette) submergence and the deposition of new sediments. The narrow transverse depressions were filled up, the deeper valley northwest or west of the lineal hill ridge was not, and with re-elevation the former outward flowing rivers would be deflected into this trough, failing to recover their ancient channels that crossed the coastal plain to the ocean. In this way the littoral rivers would have been (and some southward tilting of the drainage basin may be invoked) turned southwesterly down the vale, behind the wall of hills, and "finally escaped seaward through the partly filled depressions of lower transverse stream valleys." And Fig. 37 shows this changed result, which probably remained constant with deepening channels and more and more accentuated drainage, the small streams forming on the eastern slopes of the hill ranges being unable to capture again these swelling trunk lines of flowage.

Thus, the Connecticut and Housatonic Rivers turned westward into the Long Island Sound depression, and regained the ocean by the Hudson River cañon; the Delaware River also turned sharply, and finally flowed into Delaware Bay; the Susquehanna River turned southerly and became confluent with the Potomac; and the Potomac, instead of crossing Maryland, submitted to the lateral thrust and entered Chesapeake Bay.

Succeeding the previous formations the great Ice Age dawned, and a varied series of Quaternary deposits completed the outline and raised the superficies of Long Island. The coarser, more obvious, and latest features of this remarkable invasion—their popular expression—are described in the accompanying section, but underneath the morainal heaps a succession of gravels, clays, and sands interpret climatic and physical mutations connected with the advance, the retreat, and wasting away of the land glaciers. The so-called Pleistocene formations on Long Island have been separated into the following divisions from top to bottom:

Wisconsin Stage.—Morainal lines, outwash and kettle plains.
Vineyard Interval.—Elevation of land, erosion.
Tisbury Stage.—Depression, great deposits of sand and gravel.
Gardiner Interval.—Ice withdraws, land lower than to-day, erosion.
Gay Head Folding.—Ice, and crumpling of the surfaces of older deposits.
Sankaty Stage.—Ice withdrawn, clay and sand beds.
Jameco Stage.—Ice; filling of Sound Valley, gravel, boulders.
Past Mannetto Erosion.—Ice withdrawn, long erosion, land about 300 feet above present sea-level.
Mannetto Stage.—Ice; 300 feet depression, gravel of West and Wheatley Hills.

The above scheme should be read from the bottom to the top in order to grasp the sequence.

The Mannetto quartz gravels have been largely rearranged or removed through the processes of change in the succeeding epochs, and they are preserved in the Mannetto (West) and Wheatley Hills. These eminences are in the middle of the island, south of Huntington. Following the Mannetto gravels, the land was raised and erosion reinaugurated with the glacier outline somewhat shrunk.

The Jameco gravels succeed, and they are found underlying Brooklyn and in western Long Island. The Long Island Sound valley was in a measure filled up with these dark sands and gravels, the water from the ice edge, which stood near the north shore of the island, pouring westward in channels which may have been deeply gullied beneath Brooklyn. On the south the Jameco beds form important water-storage reservoirs.

The Sankaty Stage saw a renewal of the ice advance and finer sediments with contrasted lignitic, swampy, black clays, shallow water shells, and cleaner, deeper water-beds, with a considerable molluscan fauna. Some of the Brooklyn borings show this bed to have a thickness of 150 feet in the neighborhood of the deep drainage valley under Brooklyn itself.

Then followed a period of folding, in which the glacial beds along the north shore of Long Island and the island eastward (Gardiner's Island and Martha's Vineyard) were strangely and conclusively bent, and contorted, and compressed. This is attributed to the weight and dragging of superincumbent ice. The layers were clayey, and not so resistant as the later gravels would have proven, and the ice sheet was well extended.

The Gardiner erosion interval sheared off the caps of the Sankaty folds, and as this has been referred to wave action, the land was proportionally lower to permit the transgression inward of the ocean. The Tisbury or Manhasset gravel accompanied a great depression, and the formation is one of gravel and sand which surmount the folded clays of the Gay Head deformation. It is found at Hempstead Harbor in sand pits, stratified with included layers of boulders, and has now some 200 feet elevation above tide. It attains a maximum thickness of 150 to 250 feet.

It is supposed by Veatch that the well-marked harbors, heading valleys, and sulcations of the north coast of Long Island were well advanced, as topographical features, before the Tisbury deposits were laid down. These deposits served to deface and blur this older relief. "They continued the filling of the Sound Valley across western Long Island, which was begun in the Jameco epoch, and buried the deep valleys which had been developed in the northern portion of Long Island by streams flowing into the Sound River."

The Vineyard Elevation came next in the physical evolution of Long Island, and it is fancied that the choking up of the passages in the old Sound water-way in western Long Island caused the Housatonic and Connecticut Rivers to turn eastward and escape to the ocean through a demonstrably deep channel between Plum and Fisher's islands and Montauk Point and Block Island. Then also the filled-up north shore valleys of the island were re-excavated. It was a long interval of erosion.

The Wisconsin Stage preceded the Recent, and left the wholly remarkable testimony of its work in the great moraines that cross Long Island from end to end and also cross each other. These long mounds, heaped upon previous deposits, whose hidden saliency causes them to appear more voluminous than they really are, have at points on Long Island a height above tide of 400 feet. The Wisconsin moraine has given to Brooklyn its higher elevations in Prospect Park, Greenwood Cemetery, the ridge at Bay Ridge, and at Fort Hamilton, though from 192 feet at Ridgewood, Brooklyn, it thins away to a few feet at Babylon. It is distinguished by large *erratics*.

The Wisconsin moraine is typical boulder till, unstratified drift, and reworked drift, *viz.*, more or less stratified. It is an accumulation at the edge or near the front of the ice sheet, so far as it is a terminal moraine; beds formed under the ice sheet or ground moraines; and frontal wash plains, deltas, and kettles. The frontal wash plains have arisen from the drainage from the glacier, reassorting and separating mechanically transported burdens of sand and clay and influenced by wave action from the sea; the deltas are fan-shaped deposits left by spreading streams from higher points; and the kettles are holes or funnel-like depressions left by melting ice masses, whose included mineral contents or loads heap up around their positions a wall of débris, which may finally frame a pond or lakelet. The two moraines alluded to are shown in Fig. 38, fom Veatch's monograph; the more southern, passing through the Montauk arm (South Fluke) of Long Island, is prolonged eastward over Block Island, Martha's Vineyard, and Nantucket. This marks the Ronkonkoma stage of the ice sheet. The inner and northern which crosses the southern moraine towards the west, and delimits the eastern edge of the harbor

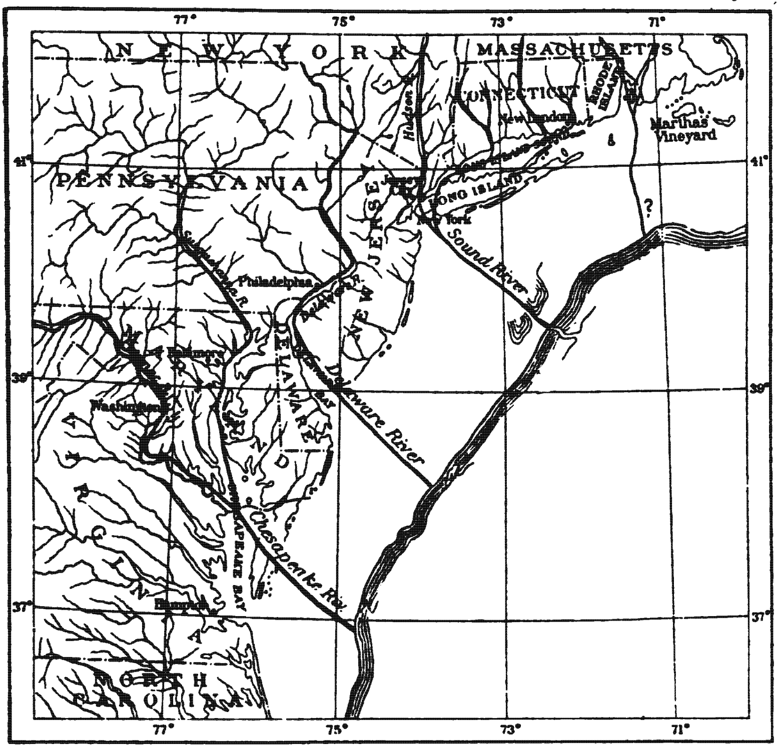


Fig. 37. Subsequent drainage lines of rivers.

Fig. 39. Harlem River defile.

Fig. 40. Dolomite beds at 149th Street and Third Avenue, Bronx, above Mott Haven.

of New York, is also prolonged eastward, passing through the Orient arm (North Fluke) of the island, crossing Gardiner's and Fisher's islands and the Elizabeth islands to its falcate attenuation in Cape Cod. This marks the Harbor Hill stage of the ice sheet. Both of these ridges are obvious to anyone coming west from the eastern end of the island.

It is clear that the Wisconsin Epoch was one of changing conditions, and that it doubtless embraced subordinate stages, as the ice cap advanced and retreated, or more significantly as it halted in either its advance or retreat, and inaugurated a train of localized phenomena. Professor Jay B. Woodworth

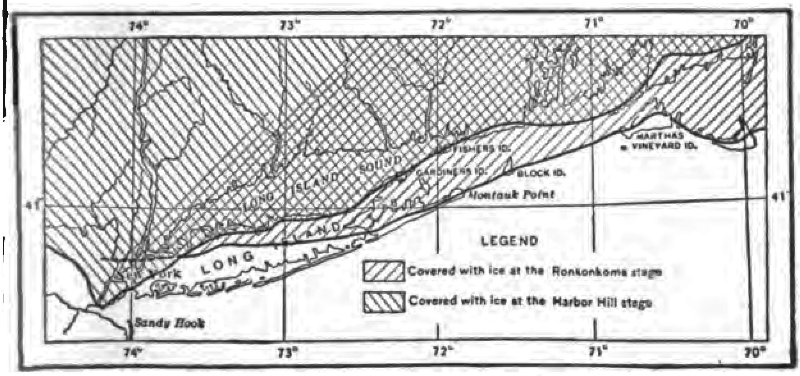


Fig. 38. Sketch map showing relative positions of the ice during the Ronkonkoma and Harbor Hill Stages of the Wisconsin Period.

has analyzed and described one of these. Professor Woodworth has scrutinized the glacial monuments on Long Island, so far as they intimate the last phases of glacial history. He has especially examined the areas about Manhasset, Port Washington, Hempstead and Oyster bays, and westward. He recognizes, as all the glacialists do, the double moraine line and the oscillation westward and south of the line of drift deposition. Harbor Hill becomes one of the highest of the drift hills (400 feet), a mound of stratified gravels formed along the ice-front, possibly by the dirt-laden streams pouring over the ice or spouting outward from imprisoned rivers. The ice-sheet we may infer was at least 400 feet high, as high certainly as the hill. "Such an elevation," Woodworth remarks, "of the ice-sheet increasing northward over the sound and on the mainland would give great hydrostatic pressure to the subglacial drainage, the effect of which would be to produce violent discharge at the front in any direction, outward or upward, in free coursing streams on the one hand, and in fountains along the crevassed, drift-blocked ice margin on the other hand, in the manner of the discharge from the border of the Malaspina glacier, as described by Russell. An overladen stream scouring the gravelly bed of the glacier, and rising at the front through a shaft to a point of discharge on the margin, would drop that material at the margin in a high cone, whose ultimate form would depend on the degree to which it was deformed by irregular deposition on buried masses of ice, the melting of which would let down these huge kamelike heaps of gravel in the form of mounds along the ice front."

The two moraines unite near Roslyn, the inner crossing the outer and continuing on into the expanding and arched elevations, on the west in Brooklyn and at the Narrows. The moraines extend east, and are separated by a varying interval which is 25 miles at Nantucket and Cape Cod, 5 to 10 miles in the Vineyard sound region, 10 miles on Block Island, with increasing convergence on Long Island. These contrasted morainal discharges not only represent a fluctuating ice front, but a secular modification in the main movement of ice. That is, on Long Island, the outer moraine distinguished a more northerly and southerly transgression of the ice, the inner, which submerges and absorbs the outer in the vicinity of Roslyn, a more northwesterly and southeasterly transference.

Both were sculptured by streams; torrents emptied down their frontal exposures; cloves or passes have been cut in them. These are noticeable at Jamaica, Little Neck Bay, Manhasset Bay, Brookside, and East Norwich. Reassortment of sands or clays occurred upon their southern and northern sides, the former dipping into the broad wash plain which sweeps seaward (15 feet to the mile) to the drowned edges of the land at the shore of the ocean. The streams which reasserted the pre-existing re-entering bays on the north side of the moraine, and which to-day are seen as emarginations, or angular flooded recesses, were developed as the ice front shrank from the moraine. It held between its retreating face and the morainal slope, on the south, an included body of water in which again new deltas and fan-shaped plains of sand were formed. Some such chancery of the waters issuing from the glacier is designated by Woodworth as the Port Washington Stage.

In order, however, to determine whether in such a confinement the water was the glacial water or moving tides, he has had to determine whether there was a partial submergence of the island, in which case the deltoid formations he has traced at Manhasset might be purely marine in derivation. He traces a shore line 2 to 3 miles east of Jamaica at about 80 feet above the sea level, on the front of the moraine; he has observed the steep margin of the moraine west of Prospect Park and finds no evidence of sea action there, but eastward, at Oyster Bay, there is controvertible evidence of a sea plain at 60 or more feet elevation. This coincidence (about) with the Port Washington level might argue for a common marine level in front and back of the moraine. The Jamaican *depression* is here introduced as the cause of a deformation, a wrenching, in its connection with the higher levels, of the underlying coastal plain formation anterior to the completion of the moraine and its frontal plain. The Jamaican Bay depression, it may be said, is a distinct subsidence, produced possibly by the weight of the ice on soft clay beds, accompanied by the partial elevated Far Rockaway ridge, raised by isostacy. Crease lines of drainage converge in all directions to this depression. (Veatch regards Jamaica Bay as a vestige of the earlier Sound River basin, partially filled.)

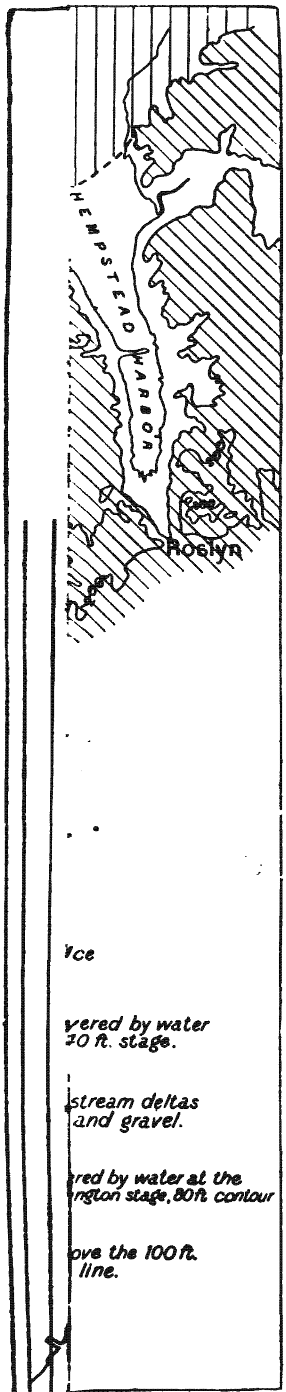
In this way Woodworth establishes his Port Washington glacial lake (Map III.), the banks of which were the ice front on the north and the moraine on the south. It drained westwardly from Hempstead Harbor into Manhasset Bay (shown by arrow), and southerly through eight or nine low passes between Maple Grove and Prospect Park to the frontal plain, the ice close to the moraine arresting any escape of the waters into New York Bay north of the Narrows.

Professor Woodworth has described a College Point delta resulting from a retreat of the ice front from its Port Washington position, involving a changed outline to the glacial embayment and possible escape of its waters through the northwestward course of Newtown Creek to the East River at Hunter's Point, or, "if that way was still blocked by the ice sheet, along a more southerly course between Williamsburg and Brooklyn into Wallabout Bay," while from Wallabout Bay a winding passage permitted discharge into Gowanus Bay, north of the Narrows.

The morainal contributions to Brooklyn topography are unmistakable, and long after the main ice-sheet had receded, outliers, melting in self-created depressions, formed upland lakes, or through the erosive action of the waters, from their dissolution, parceled out and stratified the confused débris around them. The recent period succeeded, with perhaps a sinking coast line of the island, wave action along its shores, growth of spits, bars, and narrowly enclosed bays. As illustrating its mutations of level, and phases of condition, only recently in Fulton Street at the corner of Hoyt, at a depth of 45 to 50 feet, beach sand was uncovered with shells of the hard-shell clam (*Mercenaria*) and common oyster (*Ostrea*): (Charles O. Zeller).

The water-bearing beds are in the Cretaceous and Pleistocene (Quaternary) gravels; the porous character of the ground on Long Island favors the percolation of the waters, and evaporation is reduced; there are flowing or artesian wells, but not commonly, on the island, and the "perched water tables," as in the Mountain Mist Springs in the West Hills, are due to elevated impervious clay beds with a higher watershed about or behind them. On the West Hills the springs are 280 feet above sea level, but the land rises behind them

MAP III



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140 feet higher. The area for flowing wells is placed along the southern skirt of the island from Coney Island to Valley Stream, to Babylon, to Patchogue, to the Moriches, to East Quogue. A record of a well boring, taken from Mr. Veatch's exhaustive report, is here given, showing the penetration and rock succession in Brooklyn.

BROOKLYN WELL, No. 23, BROOKLYN AQUEDUCT

Wisconsin and Tisbury.	Feet.
1—Yellow sand	0—8
2—Gray sand, water bearing	8—36
3—Coarse gray sand, water bearing	36—52
4—White sand, gravel, and clay	52—74
Transition.	Feet.
5—Yellow sand, water bearing	74—78
Cretaceous?	Feet.
6—Clay, sand, and gravel	78—100
7—Clay, sand, gravel, and wood	100—106
8—White sand, clay, and wood	106—130
Cretaceous.	Feet.
9—Sand, dark clay, and wood	130—148
10—White sand, clay, and wood	148—168
11—Sand, gravel, wood, and blue clay	168—172
12—Blue clay	172—185
13—Sandstone, iron ore, and wood embedded in black clay	185—198
14—Wood and black clay	198—202
15—Fine white sand, wood, and clay	202—220
16—Sand, wood, and blue clay	220—247
17—Blue clay and iron ore	247—260
18—Sand, wood, and clay	260—276
19—Sand, wood clay, and iron ore	276—282
20—Sand, clay, and wood	282—296
21—Hard pan, iron	296—298
22—Blue clay	298—312
23—Sand, wood, and clay	312—367
24—Clay, with a little sand	367—374
25—Sand, wood, and clay	374—390

Other localities than those mentioned above for cretaceous plant remains have been Little Neck, in Northport Harbor, Elm Point, on Great Neck, Centre Island, Dosoris Island, Oak Neck, Montauk Point.

Dr. Merrill's description of the underlying rocks of Brooklyn 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 7th 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 crossfold, 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 high-water mark at the foot of East 123d and 125th Streets, which are now obliterated. Some narrow anticlinal ridges of Fordman 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 Long Island City, Ravenswood, and Lawrence's Point.*"

The features of the glacial drift on Long Island in Brooklyn are repeated with perhaps more striking details on Staten Island, and in the chapter on "Evidences of Glaciation in and about New York" their broader aspects are reviewed.

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 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, and more directly south between Fordham and the highland on the Hudson.

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 pendant 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.

Professor 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 typically 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 schist*. 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 Professor Merrill is absolute 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 biolite, *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 7th Avenue and Northern Boulevard. And then the mica schist or very micaceous gneisses of New York Island.

The so-called Poughquag quartzite, previously mentioned (p. 7), may be represented at Morris Docks in this borough by a very siliceous schist (see Fig. 5), but it cannot be regarded as very significant, and its reference to the Potsdam is certainly erroneous. Professor Berkey has definitely sundered the Lowerre standstone from the Poughquag (north of the Highlands), and the Lowerre and this Morris Dock film naturally become exceptional aspects of associated gneisses, and nothing else.

An instructive review of topographical features in the Bronx is afforded by crossing from the Subway Elevated Railroad station at 174th Street to the Harlem River: dark gneiss ridges are seen on 3d Avenue and Jackson Avenue further south, with low, smoothed, abraded gneiss hills and intermediate depressions generally declining towards the Sound and East River, where marshy emarginations, resistant strips of rock and islets compose an immature coast line. From

174th Street westward the observer first passes over the rounded degraded knobs of rocks in Crotona Park, at a considerable elevation, surmounting a sharp rise from the West Farms section, while Crotona Park itself reveals a folded area. The exposures of gneiss in Crotona Park show in places a very slaty and fissile rock, with corrugated beds and granite veinings. Morainal heaps and alluvial coverings hide or bury the gneissic contours, seen somewhat markedly at Third Avenue and 175th Street. Next succeeds the Tremont gulch or channel, steeply walled by the ridge at Echo Park, where a strong development of white gneissoid granite is seen, sheathed in gray flexuous ribbons of mica schist. To the west again, as the hill slopes to Jerome Avenue, a vast hill of glacial sand occurs, through which the trolley tracks pass by a tunnelway. Westward by Tremont Avenue another ridge is crossed made up of laminated, upturned mica gneiss, its scars and erosions molded into a smooth hill by alluvial and drift accumulations of soil and sand. In places the rock becomes granitic though retaining a gneissoid structure. On Aqueduct Avenue, at the top of this ridge, granite developments of considerable volume occur. A *till* with boulders is seen north of the Public School, from whose western porch the Harlem valley is commanded, the Fort George Heights, and, through the Dyckman Street intervale, the wooded crests of the Palisades. This last ridge is heavily banked with drift on the west. South again along Sedgwick Avenue towards Washington and High Bridges, the gray gneiss, fine-grained, folded, and swerving in thin sheets, is conspicuous. Low cliffs of the gneiss have been well exposed north of 161st Street on Mott Avenue. The topographical expression is clearly north and south ridges and separating valleys. This is continued westward over Manhattan Island to the Hudson, with an accentuation in the Harlem River defile, possibly deepened by faults (Fig. 39).

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 Williamsbridge; and it may be so with Westchester and West Farms Creeks.

These limestone beds were traversed by the Subway tunnel under the Harlem River, and a deep, open cut made in them (Fig. 40), at 149th Street, toward Third Avenue, brought in view their crystalline integrity, and bedded structure. Limestone beds are seen at Jerome Avenue reservoir, where actinolite, titanite, pyrite, pyrrhotite, orthoclase are developed in a metamorphic seam. (J. H. Adams.)

NOTE.—Mr. Edwin W. Humphreys has furnished me with the following epitome of his observations in a Pleistocene or recent swamp in the Bronx Borough:

"Situated in the valley which is just back of Claremont Park, Bronx Borough, is a most interesting swamp. In it, a thick deposit of peat has accumulated. The forcing up of the peat by the filling in of a street across it, some years ago, revealed the following fossil shells, *Valvata tricarinata*, Say, *Planorbis parvus*, Say, *Planorbis bicarinata*, Say, *Physa heterostropha* (?), Say, *Amnicola limosa* (Say) Hald, *Pisidium virginicum* (?) (Gmelin) Bourg."

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 van Kull, New York Harbor, on the north, and the ocean and Raritan Bay on the east and south. It contains about FIFTY ~~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 northeast and southwest 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.

Again, when in August, 1905, it was found necessary to blast the rock under water at the site of the new ferry slip at St. George (the northeastern point of Staten Island), mica schist containing garnet, and unmistakably homologous with the Manhattan phases, was brought to the surface. Near at hand in the Robin Reef rock, connecting by a low submerged (at high water) ridge with Ellis and Bedlow's (Liberty) Islands, similar or identical formations are discovered, and while it is probable that underneath Staten Island, as generally west of the Hudson River channel, these schists dip steeply and pitch below the mesozoic basins, they constitute for the Borough of Richmond, as for all the other boroughs of the Greater City, the fundamental lithological substructure as an ultimate reference.

Upon the serpentine hills as a center 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 van Kull and New York Harbor and, with a fairly uniform range of elevation, extend to Richmond, at the center 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 van Kull, and at Graniteville (Fig. 41), represents the *Triassic* rocks, the first stage of Mesozoic time. There are no Paleozoic rocks on Staten Island in place, 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. As far back as 1843 W. M. Mather, in his Geology of the First Geological District (New York Geological Survey), alludes to this outcrop in these words: "In Richmond County (Staten Island) the red sandstone occupies but a small area where it can be observed, but from the observations made by Professor H. D. Rogers and myself it is believed to range from between Bergen Point and Shooter's Island, south-southwestwardly, to the Freshkill marshes. It is generally covered by soil drift deposits, and the sand and clay beds. It may be seen at very low tide, on the shore, about southwest of Bergen Point. It is the slaty, micaceous, fissile red sandstone and shale." This locality is on the north shore (Mariners' Harbor) of the island, on Newark Bay, and the occurrence is now obliterated by building and occupation. Dr. Arthur Hollick determined the same formation (Triassic) in the railroad cutting beyond Arlington station in this vicinity, and later (1908) "in the vicinity of Kreischerville (west side of island on the Arthur Kill) accidentally discovered an outcrop of Triassic rock on the east side of Sand Lane, near Bogardus' Corners. The rock is red, shaly sandstone, thinly bedded, and presenting evidence of having been squeezed or crushed, probably by ice action. Its presence at this location, at an elevation of about 140 feet above tide, is somewhat remarkable, as it indicates that the topography of the region is not wholly due, as was formerly supposed, to eroded cretaceous strata and drift deposits, but that it is due, at least in part, to 'bosses' or ridges of older rock." The protruding dike of "trap" still remains the most evident witness to the Triassic. The trap on Staten Island represents the disappearing prolongation of the Palisades, and is either actually less voluminous than the flows, continuous with it northward, or is an imperfectly emergent strip, the superficially thinning end of a curviform arch that attains, on the State line between New York and New Jersey, an altitude of 547 feet, and 1,000 feet in the High Torn near Haverstraw.

The trap rock (diabase) is familiar 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 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.

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 Greater New York. And in this way: Professor 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 extending 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

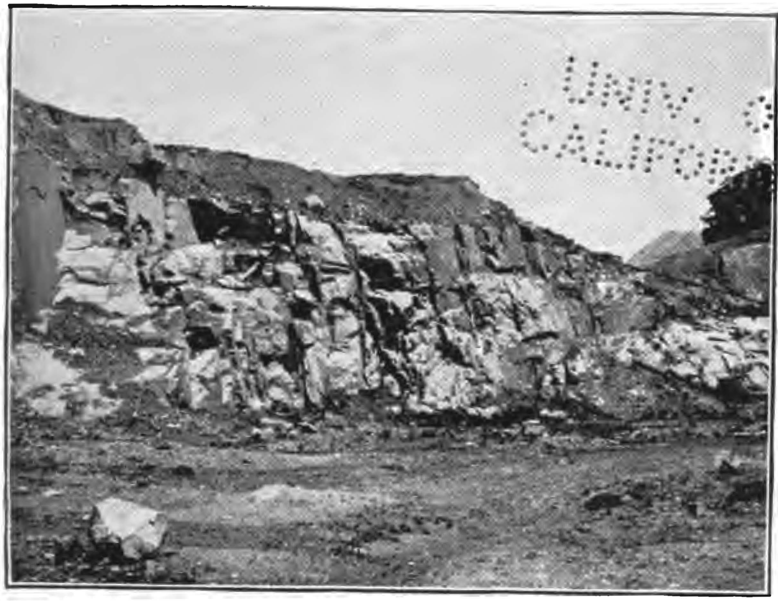

Fig. 41. Trap Rock at Elm Park, Staten Island.

Fig. 42. Clay beds near Kreischerville, Staten Island.

Fig. 43. Clay pit, Kreischerville, Staten Island.

Fig. 44. Androvette sand and clay pit, Kreischerville, Staten Island.

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 *possibly* archæan 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 the Arthur Kill.

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. 42.) 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. Dr. 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 granite 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 Cretaceous formation as a whole embraces a number of beds overlying one another upon a gently sloping plane which was produced seaward along the present coast line of northern New Jersey, and which crossed that State, extending southward. Clays, marls, sands, and iron sediments were deposited in the cretaceous sea, and the plastic clays of the Raritan River were either amongst the earliest of the cretaceous beds or belong to the end of the preceding formation. These beds, well represented near Matawan, New Jersey, and bearing a somewhat distinctive fossil fauna, form presumably the cretaceous areas of Staten Island. Amongst floral remains found in the clay beds at Kreischerville, Staten Island, were evidences of *Sequoia, Widdingtonites, Eucalyptus,* and *Proteoides,* plants belonging to this period, and expressive at least of a semi-tropical climate. At Tottenville, Princess Bay, and Arrochar hardened clay spheres and concretions, doubtless torn from underlying cretaceous beds, and now distributed in the overlying drift accumulations, contain plant remains also, as made out by Dr. Hollick, distinctly cretaceous, being *Liriodendropsis, Laurus, Thrimfeldia, Sapindus, Mariconia.* These masked or covered cretaceous beds are probably gently rolling, and were marked by some unevenness and by synclinal troughs or basins. Where these beds approach the surface their fossils have become mingled with the superincumbent drift, where deeply removed, the heavy covering of drift completely conceals the latter.

But the evidence, the unmistakable included testimony of numerous plant remains, has in very recent years reached distinguishable proportions, and the most interesting discovery by Dr. Hollick of *Amber* in these beds, and its probable origin, imparts a new status to all previous speculations, with no inconsiderable thrill of geological reconstructive picturing also. The record of the plant genera, and the localities in which they were found, should be perhaps more extendedly reviewed, as illustrative of the only indigenous fossils (if the expression can be used) in Greater New York. They are:

Protophyllocladus (Tottenville and Princess Bays), *Dammara* (Tottenville and Kreischerville), *Sequoia* (Kreischerville), *Widdingtonites* (Kreischerville), *Moriconia* (Princess Bay), *Cyparissidium* (Tottenville), *Majanthemophyllum* (Kreischerville), *Populus* (Tottensville, Arrochar), *Salix* (Kreischerville, Arrochar), *Myrica* (Kreischerville, Tottenville), *Juglans* (Tottenville), *Querulus* (Tottenville, Arrochar), *Salix* (Kreischerville, Arrochar), (Tottenville), *Menispymilis* (Tottenville), *Magnolia* (Tottenville), *Liriodendron* (Tottenville), *Laurus* (Kreischerville, Tottenville), *Laurophyllum* (Tottenville), *Platanus* (Richmond Valley, Princess Bay), *Dalbergia* (Tottenville), *Leguminosites* (Kreischerville), *Pistacia* (Tottenville), *Acer* (Tottenville), *Sapindus* (Princess Bay, Tottenville), *Paliurus* (Tottenville, Kreischerville), *Stercula* (Tottenville), *Eucalyptus* (Tottenville), *Aralia* (Tottenville), *Chondrophyllum* (Kreischerville), *Kalmia* (Kreischerville), *Andromeda* (Tottenville), *Myrsine* (Arrochar), *Diospyos* (Princess Bay, Tottenville), *Dewalquea* (Tottenville, Kreischerville), *Phyllites* (Kreischerville), *Williamsonia* (Kreischerville), *Tricalycites* (Tottenville), *Carpolithus* (Tottenville, Kreischerville).

The impression made by this floral exhibit is that of a warm temperate or sub-tropical climate. The poplars, willows, walnuts, oaks, magnolias, tulip trees, plane trees, maples, ginsengs, laurels, rosemary, persimmon, bay berries, might not demand a very sensibly different climate from that now prevailing over the very spot where their tell-tale relics are exhumed to-day, and we might assume that indeed the Cretaceous areas of the United States enjoyed somewhat contrasted temperatures with reference to their northern or southern position, as that the palms were present in the southwest, but absent on Staten and Long Islands. To assume only a moderately temperate environment from the presence there of these existing genera would, however, be a narrow and stilted interpretation. They are genera which adapt themselves to warm conditions, or may encounter them without danger of extinction, and when we note *Dammara, Eucalyptus, Sequoia,* the pines (*Widdingtonites, Moriconia*), Ficus, Proteoides, Pistacia, plants loving, or flourishing under, warmer circumstances of climate, we are compelled to admit the implication of a sub-tropical facies to the flora; palms present elsewhere in the latest Cretaceous or lower tertiary have not been cetainly found in the lower and middle Cretaceous, and, at any rate, are absent from Staten Island. There is a reason, perhaps, for vindication of a more composite conception. There was a mingling in those Cretaceous years on Staten Island (if indeed it was an island) of a northern and southern flora, as there is to-day, when the denizens of the New Jersey pine barrens fraternize with the residents of New England in the same region.

We may call to mind a deeply foliaged, low, outstretched forested plain, with sluggish streams, embayments, fresh-water lagoons, and swampy ponds, on which a sun of semi-tropical intensity shone with changing accidents of storm and flood and steaming fog, while a persistent sedimentation in the whirling or quiescent waters built up the clay reefs, shoals, and beds.

In addition to the plant remains, *amber* has been found in these Cretaceous clay pits by Dr. Hollick, from whose attractive essay on his discovery a few excerpts follow. "The amber," he says, "occurs in a stratum or bed characterized by layers, and closely packed masses of vegetable débris, consisting of leaves, twigs, and fragments of lignite and *charred* wood. Pyrite, in nodules, is also a prominent constituent." The amber was "more or less transparent and yellow or reddish in color, but much was opaque and grayish white." The pieces vary in size from drops to irregular pieces as big as a pin's head or a hickory nut. Amber has been taken in the Cretaceous of New Jersey.*

The geological visitor to Staten Island will find the clay pits of Kreischerville interesting, and one or two of them, hidden in the woods, pleasantly stimulating pictures. The itinerary may be accomplished in this way: Take the Staten Island railroad train from St. George and alight at Huguenot, or Princess Bay, or Pleasant Plains, or Richmond Valley stations. From these stations on the southern or southeastern side of the island roads pass over the elevated ridges westward to the west shores of the island on the Arthur Kill, where the Kreischerville deposits are found. The best objective point is Rossville (reached from Huguenot, Princess Bay, or Pleasant Plains, by carriage, 'bus, or on foot), and this point gained (distinguished south of the village by a beach-like bluff), the traveler will follow the road southward to Kreischerville. A short distance beyond Rossville, beyond the Cemetery (on the right), and while the road is yet bordered by the woods of the Ultra-Marine works, a gulch or track-cutting is met crossing under the road; this leads from a white clay-pit some thousand feet back (Fig. 42) on the left. The surface soil is drift and the clay has a depth below the forest soil above it of 12 to 18 feet. Piercing the woods and pushing through a straggling colony of negro tenements, a deeper deserted pit is reached, framed in *Pinus inops,* and yawning somewhat cavernously, with a depth of 20 to 25 feet.

Returning to the Rossville-Arthur Kill road and continuing southward, the Androvette pits are first reached on the right towards the summit of a hill. The amber was taken here. (Fig. 43, 44.) Passing this, the long clay escarpment or flank on the left is met beyond the brow of the hill and looking

*Messrs. E. E. Jeffery and M. A. Chrysler (Botanical Gazette, Vol. xlii, 1906) describe results from microscopic examinations of Kreischerville lignites. They identify the coniferous fossil genera *Araucarioxylon, Cupressinoxylon, Pityoxylon.* These botanists found amber in the lignite, in a nodular form and as yellow threads "corresponding to the normal resin passages of the wood." The Kreischerville lignites also show insect borings. Insects from the Cretaceous are scarcely known.

down a slope to the factory site of the Kreischerville tile-pipe works.

Some of the clay exposures are colored in strips; sands overlie the clays unconformably; some pits are almost entirely in sand with ferruginous infiltrations; the depth may be two hundred feet; the country is undulating, knobby, and disturbed. Kreischerville can be directly reached from the Richmond Valley station by carriage.

Dr. Hollick shrewdly observes that "the Cretaceous area is of importance as the region from which a permanent water supply may probably be obtained. Throughout the area underlain by Cretaceous strata a reliable water supply may probably be obtained by wells driven to the proper horizon."

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 very notable Quaternary fossil was uncovered on Staten Island in the Moravian Cemetery at New Dorp, in a swampy depression filled with decaying vegetation. Beneath the usual accumulations in such basins, sand, logs, and cones were found. The cones belonged to the white spruce (*vide* Dr. A. Hollick), *Picea canadensis*, a tree of a high northern range. "The spruce cones were at a distance of about ten feet from the surface, distributed in considerable numbers in a layer about a foot in thickness, while below this was found a *mastodon's* tooth at a depth of about 25 feet. The entire deposit bore every indication of having been laid down in still water in a continuous and unbroken series of layers, and inasmuch as it was in a morainal basin it must all have been post-morainal in age." (Proc. Nat. Sci. Ass. Staten Island, Vol. VII, p. 29.)

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 right, 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 Princess 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 alongside 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 of 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 extruded 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 serpentine nucleus of Staten Island has been regarded as an area of eruptive rock, and thin sections of the rock, from an outcrop near Martling's Pond, a mile northeast of Castleton Corners (Four Corners), and near the turnpike that traverses the island from Clifton to Linoleumville on Long Neck, have revealed the presence of olivine, a very common mineral element in basaltic rocks, in diabase, gabbro, and related igneous dikes. The detection of olivine is rare, and while it is a fair inference that the serpentine is identical in its origin throughout, the deduction from this sporadic occurrence that the Staten Island serpentine is derived solely from igneous rocks may be questioned. Dr. D. H. Newland, who made this discovery, also remarks that near Castleton Corners, "where, in excavations for the foundations of a building, the rock has been exposed to a depth of several feet," the presence of shining bronze prisms "imbedded in a ground mass of dark serpentine" resembles a decomposed or altered gabbro rock. The same author, in studying the change from hornblende (amphibole) to serpentine, which change is universal in the island serpentine, describes the process in a very interesting manner: "In the first stages minute veinlets of serpentine are developed along the cleavage planes of the amphibole at the ends. From here they gradually extend toward the center, at the same time reaching out into the lateral prisms, and widening out until the crystal is entirely altered. By this process serpentine planes are developed with uniform arrangement parallel to the axis of the amphibole. In transverse sections the plates are divided into two sets which cross each other at angles corresponding to the hornblende cleavage."

Chromite, magnetite, chlorite, talc, tremolite, and iron sesquioxide occur in the serpentine. Magnesite, a carbonate of magnesia, has been found on Staten Island in connection with the serpentine; asbestiform serpentine is common, and the collector will note at its various exposures much variety in texture and color, density and physical appearance, of this remarkable lithological feature in Richmond Borough.

Pavilion Hill, back of Tompkinsville, Grant City, the hill at Garretson's, exposures on the road from Richmond to Springville, the cut at the top of Bard Avenue, West Brighton, the hill west of Clove Valley, and at points near the Hessian Brook and at Fort Hill, Jersey Street, New Brighton, are localities where the serpentine can be readily collected and studied.

The topography of Richmond Borough, its extreme interest and beauty, and the combination in it of scenic features quite absent from all the other boroughs of the Great City, will appeal to the most casual observer. The coastal plane—or rather the covered edge of that flat area stretching out to the rim of the continental plateau some hundred miles beyond Sandy Hook—extends southward like a shelf from the foot of the serpentine hills in the eastern section of the island's southern coast line (from the fort at the Narrows to Great

Kills), and changes gradually to higher undulating bluffs, where the morainal hills plunge into the sea at Princess Bay. Intermediate between the morainal wall and this flat land is a diversified country, rising southward and holding, near the sea, bowls of fresh water, with fields where fish-hawks haunt old apple trees, or tatterdemalion acres of weed and grass and shrub alternate with more comely and presuming farm land. Groves of cedars, meandering creeks, scattered remnants of woodland, old deserted houses looking seaward from their eyeless windows, blanched by the cold salt winds, falling wearily to ruin in the arms of creeping tendrilous plants, but holding hard onto life yet with their strong floors and enduring beams, yield lovely pictures.

The sea line rising into steep gravel cliffs at Princess Bay, here and there where some distinction of color or form as a tree, lighthouse, or moldering dock, intensifies the foreground, offers bolder and different scenes.

On the northwestern border of the island, leaping right over the middle hill country, the observer enters a unique and isolated community, living in a region of sand-dunes, marshes, creeks and pene-Saharal loneliness.

Here is Watchogue, or Watch-oak (reached by Thompson's Road from Arlington station on the Rapid Transit Railroad), where the delusive edges of the island dip beneath the waters of Staten Island Sound, showing resistant centers which refuse submergence in island-like dunes, forks, and points of land. Northward and southward from Watch-oak is much meadow land.

But the interior of the island within and around and on its belt of serpentine hills, with their many features of extreme attractiveness, their wide outlooks, their ponds and trees, houses, roads, glades, valleys, and distances, will more keenly attract the visitor. Richmond, an old hamlet and former county seat, is at the center of the island. It lies at the foot of the serpentine hills that terminate in the slope of the Old English Fort, and catches a glimpse of the ancient Latourette farm-house, still standing in the midst of the paternal acres on the summit of the serpentine ridge. The highest point of the island is almost 400 feet.

South and west of Richmond rises an undulating country composing the third topographical section of the county. Herein are abundant elements of pictorial and geological interest, which may be encompassed by following the road from Richmond to Rossville, thence reaching the rolling country-side above Jessop's farm, on the long lane to Huguenots, and returning by Woodrow, a tour which, if wisely interspersed with ramblings right and left, will show some range of surficial deposits and formations.

In the development of the Greater New York the direction southward of its population must gradually prevail, and the shore fronts of Staten Island become occupied with docks and shipping, while all its hills, commanding beautiful views of the Lower and Upper Harbors, cannot fail to assume a strictly municipal aspect by the growth of splendid homes of architectural beauty and structural permanence.

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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 spread its icy surface over the polar lands became so expanded as to hide the surface of the earth within its frigid folds down 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 trepi-

*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.

dation, 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 débris far and wide over its plains. The conception was a bold, almost a terrifying one, and because the actual history and nature of glaciers were 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's 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 grooves, of all dimensions, pass over the rocks in groups, like moldings, and the rocks they occur upon are polished and oftentimes lustrous. The channels diminish in size to the faintest striæ 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, scoring 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 northwest and southeast, 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 northeast and southwest. In the east they assume a rudely outlined radiation from the highlands of Canada, and stretch out from a hypothetical center 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 pinnacles 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 striæ 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 them.

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 striæ 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 striæ; 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 strewn 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 Antæus. 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, Magdeburg, 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 picturesquely, *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. Professor 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 Northwestern 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 southeasterly 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 Menominee 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 exercised 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 striæ, 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 centers 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 these phenomena are the appearances known as crushed ledges and *roches moutonnees,* 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 laminæ 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 moutonnees 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 moutonnees* 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 longer 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.

As regards more in detail the circumstances and features of the Ice Age in eastern North America, it can be safely concluded that so momentous a climatic alteration began and progressed over a long period of time. And further, that its phenomena, the ice, and its action were progressively intensified; that if the ice sheet formed (as, of course, it mainly did) in the north, it was a confluence, in part, of lesser units, that it may have been preceded by glacial accumulations on the high ranges in New England or in the New York Highlands, and that these, in a radial manner, north and south, may have distributed transported material, until the coercion of the more continental mass united all the local sheets and turned them southward in a comprehensive and generally continuous advance.

We are required to believe that the thickness of this ice sheet was, at a maximum, over 6,000 feet, that it crossed mountainous elevations and undeviatingly crossed valley and river gorges also, filling them up, but continuing its former unimpeded direction past and beyond them. As it finally disappeared (it is still a matter of geological discussion whether there were two such Ice Ages, with an intervening moderation of conditions in which vegetation [trees] returned to the previously glaciated districts) it probably underwent a differential dissolution, retreating more rapidly at points near the seaboard than in the interior. It thus left isolated tracts of ice upon propitious sites, ice gorges, clefts, and wedges as well, in deeper defiles, and shedding, in the last stages of its collapse (if the assumption of a general land depression is correct), from its impaired or ragged contour icebergs and ice-floes. These latter may have contributed, at points where they stranded and remained, to the formation of the peculiar *kettle* holes now seen in the glaciated areas.

Physical features developed in the whole process of denudation with its accompanying floods, to which distinct descriptive terms have been applied. It must be remembered that the inorganic burden of the glacier was *in* and on it, that much that was on top of an ice mass sank within it and became *englacial,* until it actually descended to the bottom and contributed to the formation of the *ground* moraine. This ground moraine was now mingled stones, boulders, gravels, clays, over which the ice slid, partially dragging them on or leaving them behind. There were surface streams on the ice, that made their way quickly into crevasse openings, and according to the accidents of the ground on which the glacier rested emerged, or, chilled anew, were reformed into ice.

Drumlins and *Kames* are names given to certain heaps of drift material, characteristic of drift territory. Drumlins are elongated hills made up of *till* (a clayey mixture of stone fragments, boulders, gravel, sand, the filched detritus of all sorts, of the rocks over which the glacier has passed), their longer axes lying in the direction of the ice movement. They may have been made in the ice sheet, and contributions to their increase may have been brought by the water currents of the glacier. These water currents were of large volume, and accomplished work both as carriers and sculpturing and reassorting agents of the drift. *Osars, eskers,* are ridges of drift-stuff formed on or in the ice by glacial streams, and finally deposited underneath the glacier or left bodily by the melting away of the surrounding ice. *Kames* are hills of drift material which have become *stratified;* they have resulted from water action; they are apt to lie across the direction of the ice sheet, rather than, as with drumlins, in conformity with it; they are associated usually with the terminal moraine, and the lines of stratification are often undulating; they are less like ridges than the osars, less confused in composition and smaller than the drumlins.

The moraines, and specifically the terminal moraines, reflect more cohesively the nature of the ice action than anything else. The terminal moraine is that unassorted barrow of stones, till, gravels, sand, boulders, small and large, which is interpreted as marking the extreme advance of the glacier, and which, in loops, angles, sweeping lines, and straight frontiers, crosses the United States. It is composite in construction and in age and in distribution. It may mark numerous advances of the ice; it is unquestionably a conglomerate of mineral constituents, and it varies enormously in its depth and development at different points, here covering subadjacent formations with a heap of débris hundreds of feet thick, and there just thinly veiling the older rocks. This disparity arises, of course, from dissimilar conditions in the path of the glacier's course; where there was an abundance of decayed or fragmental rock this was plowed into, pushed on in increasing quantity, and at last abandoned as a formidable mass; where there was little, the same action produced less conspicuous consequences.

One of the very interesting features of a part of the New York City (Greater New York) area is the extra-morainal glacial (or apparently glacial) drift, known as the "yellow gravel," which is found on Long Island and within the city limits on Staten Island. Its name applies distinctively. As seen at South Amboy, New Jersey, and on the front of Todt Hill, Staten Island (near Moravian Cemetery), it is mainly made up of rounded, yellow quartz pebbles. In it occur northern silicified and obscurely preserved fossils and rock transported from northern positions. As a whole, Professor Salisbury has endeavored, in New Jersey, to separate it into four formations: the Beacon Hill, the Pensauken, the Jamesburg, and a problematical fourth stage. These drift deposits (if they are *drift*) are probably pre-pleistocene; at any rate they do not belong to the *later* Glacial Age. They have undergone great erosion, possibly have been worked over by wave action, and the strongest argument for connecting them with any ice epoch is the "presence of large, somewhat widely transported boulders." (Salisbury.) This curious deposit has been also referred to the Pliocene (Lafayette of McGee). Upper Helderberg fossils have been taken at Lemon Creek (Princess Bay, Staten Island) in the yellow gravel.

DRIFT

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 leveling 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 larger 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 10th Avenue and 24th Street, a boulder of "asbestos rock" four or five feet in diameter, with boulders of greenstone (trap), granite, and standstone. The "asbestos rock" is hydrous anthophyllite, occurring at 59th Street and 11th Avenue, though it must have extended farther north.

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

At 64th and 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 8th 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. Stevens' 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 4th Avenue, near 14th Street, he observed boulders of immense size, some of which were ten to eighteen feet in diameter.

On 3d Avenue, to the East River, about 50th Street, trap, granite, sandstone, and limestone (much less frequent) boulders were recorded by Dr. Gale—all northern immigrants.

It would be wearisome to rehearse all of Dr. Gale's observations; they repeat each other continuously, 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. 45) 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 Weschester 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 smooth, 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 8 x 3 x 5 feet in cubic dimensions, or represent each in weight nearly ten tons. (Fig. 46.)

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, 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 or 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. 47). 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 van Kull on its south side, quite contrasting with the far less encumbered north shore of the same channel, were 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 center 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, granite, slates, and occasionally a limestone or

Fig. 45. Rocking stone, Bronx Park, showing glaciated gneiss surface.

Fig. 46. Drift boulder of granite, Central Park.

Fig. 47. Granite boulder at Pelham Manor, Westchester County.

Fig. 48. Granite Drift Boulder, Stapleton, Borough of Richmond.

grit "wanderer," whose absolute irrelevancy to its surroundings was shown in the fossils it revealed.

A surface survey seems to show that the trap boulders and, indeed, boulders of all sorts are numerically greater on the north shore of Staten Island than through its interior region or south of its hills. The backs and flanks of the morainal hillocks do not display so noticeable a collection, nor anywhere is the sprinkling of *large* masses of angular and transported rocks as striking. Taken in connection with the admitted lower level of the continent in glacial days, they strongly impress the observer as ice-raft or iceberg transported fragments.

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 alien masses, and the most skeptical would not withstand such indubitable evidence of removal and transference.

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. 48). 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.

The fossils taken in the drift on Staten Island belong, so far as they have undergone extreme transportation, to the Paleozoic rocks (see p. 4). They number 112, and are apportioned to the various geological members of that age as follows, in their succession: Potsdam 1, Hudson River 5, Lower Helderberg 55, Oriskany 20, Schoharie 32, Upper Helderberg 1, Hamilton 1.

It is quite obvious that their significance is limited by the three horizons, Lower Helderberg, Oriskany, and Schoharie, which, in central east New York, approach the Hudson River, and the inference is suggested that these siluric and devonic fossils have been carried to Staten Island by the Hudson River gorge *ice element* of the great glacier. In the prolongation of the direction of the few discernible striæ on Staten Island rocks, which are N. 13° W. and N. 20° W., we meet a vast development in southern New York, beyond the Highlands of Orange County, N. Y., and Sussex County, N. J., of the Upper Devonian rocks, in the sandstones of the Portage, Chemung, and Catskill; and except, as through attrition and reduction into sand, they have become unrecognizable, these rocks are not found on Staten Island. They are structurally apt to form blocks, fragments, boulders, and separate masses, through weathering. Why should not the glacier have picked them up and carried them southward. If it did not do so, the explanation is to be sought in the lofty barricade of the Highlands against which the protruding ice sheet broke, and as it overrode and enveloped them it parted with its Upper Devonian burden, to replace them south and southeast of the Highlands with *Triassic* shale, sandstone, and trap.

The Hudson River tongue of ice, or its particular stream of participation in the universal sheet, could not have been so despoiled, and it left the east central New York fossiliferous specimens as "erratics" on Staten Island, and their original position was near the Hudson River course.

This conclusion seems fortified when we consider the prevalent eastern and southern localities on Staten Island where these fossil boulders have been taken. Out of 147 localities, 85 are eastern (Clifton, New Brighton) and 52 are southern (Princess Bay, Richmond Valley, Tottenville), or beyond the serpentine ridges, on a plain, over which, by *fanning*, the Hudson River ice tongue might have spread.

The Triassic and Cretaceous fossils (the Triassic are negligible) of the drift are *involuted in the drift* at or near the place on the island where the Cretaceous occurs, and are inclosed in concretions. (For detailed nomenclature of drift fossils see A. Hollick, Some Features of the Drift on Staten Island; Annals New York Academy of Sciences, Vol. xii, p. 91.)

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 with boulders, while its backbone of low hills is also strewn with their débris. 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 Massachuetts. 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 hemisphere. 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 to Prospect Park (Fig. 49). 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 débris. 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 meager vegetation.

There is much in this Fox Hill region, on Staten Island, which partakes of a *kettle* morainic physiognomy, that is, there may have been dislodged or separated fields or pinnacles of ice here, which melted away, and heaped up circumvallating walls of rubble around their vanishing sides.

This terminal moraine touches the shore of Staten Island at Princess Bay, where about one-half a mile from the Dental Works the exposed face of the morainal hill is well shown under the lighthouse, 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 lighthouse, where the bluff has an altitude of about seventy-five feet (Fig. 50). It declines landward into an undulating plain, which largely represents drift reassorted by water.

There is a morainal bank setting round the serpentine eminences and riding up and over their slopes from Tompkinsville to West New Brighton on the north shore. Its lower portions, where cut through, show a stiff till formation. It has been broached and escarped by waves and water, and now forms a prominent terrace on the south shore of the Kill van Kull channel, declining to tide-water where an interior northward drainage at Snug Harbor has cut through and reduced it. Formerly its discharged contents crowded the shore with boulders.

The modified 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 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 conglomerate the pebbles and cobble-stones. The relative positions of the included stones often show the absence of rearrangement 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.

In the bluff at Princess Bay Light there is an underlying detrital mass of stones and sand which Professor Salisbury assigns to the "Pensauken formation," of which he says:

Fig. 49. Boulder Drift, near Water Tower, Prospect Park, Brooklyn.

Fig. 50. Terminal Moraine Hill, Prince's Bay, Borough of Richmond. Wall at foot is artificial.

Fig. 52. Morainal bank, 128th Street and Broadway.

Fig. 53. Continuation of Viaduct, looking north. 1905.

"Though not of glacial origin, the Pensauken formation was probably contemporaneous with one of the early glacial formations."

There is a small area of land on Staten Island directly in front of the moraine which seems devoid of this drift deposit. It forms a bare patch, as it were, and the moraine recedes behind it in a re-entering curve (Fig. 51). It lies around and behind New Dorp. Professor Salisbury, com-

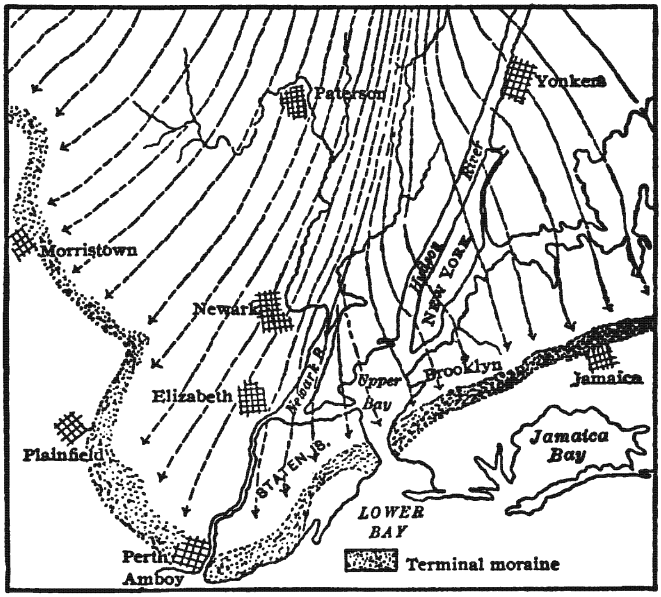


Fig. 51. Showing unglaciated edge on Staten Island.

menting on this, says: "The study of the position of the moraine in its relation to topography shows that this bend in the moraine occurs southeast of the highest point on the island. These relations are in no way accidental. The effect of the high land was to retard the movement of the ice, and the highest land retarded it most. In the lee of the highest point, therefore, the advance was least. It is significant that the ice surmounted the summit and started down its southern slope, but the thickness of ice which surmounted the highest land was so slight that it advanced but little beyond the summit, and at its position of maximum advance its edge rested on a descending slope." This is ingenious if not altogether convincing.

There is also a small area south of Tottenville, at the angle of the island, on which the moraine does not encroach.

South of the morainal region on Staten Island toward the sea the washed and distributed material of the drift is found on the surface, ending in a swampy and uneven tract, from which again develop the beach ridges of sand.

On Long Island the moraine is well developed, reaching almost to a height of 200 feet. It forms some of the rolling landscape of Prospect Park, the irregular topography of Greenwood Cemetery, and north of Jamaica and Hollis forms an abrupt and commanding bench. From it extends southward the flat plane, whose surface soils, loams, or clays have been derived from it, overlying earlier formations beneath, whose extent and depth are as yet unknown, but which will be progressively better understood as the present survey of water-bearing levels on Long Island proceeds. At Ridgewood odd-shaped polyhedral nodules have been found in the drift, and mistaken for human handiwork. They are limonitic concretions.

Morainal accumulations were formed or left on Manhattan Island, often against the *stoss*, "push" side, of the slopes of higher ground. Such a deposit occurs at 128th Street and Broadway (Fig. 52), where there was a *till* bed or bank, some twenty feet thick, with superimposed sand in slightly undulating lines—for the most part horizontal and laid down by water. This had its counterpart on the north side of the Manhattanville depression in morainal banks which could be seen formerly from the Fort Lee ferry dock (Fig. 53), and in which very considerable admixtures of dolomite sands occurred, and where, at 135th Street, between Broadway and Riverside Drive, large red sandstone boulders were emplaced.

Similar morainic material was seen eastward near the Harlem River at 133d and 134th Streets (Yeshilian). East of 7th Avenue, on the south side, in the Pennsylvania Railroad excavation, valleys in the gneiss were cut through and sunken boulders—as if they had subsided through loose layers of sand, silt, etc.—were encountered (Fig. 54). Similar sand-filled troughs or valleys were seen on the line of 33d Street, between 7th and 8th Avenues.

It seems almost certain that in the initial or final stages of the Ice Age the Hudson River ice tongue was significantly effective. *Till* ridges occur at the south end of Manhattan Island, and an action of erosion, wearing and ripping, to which Dr. Julien has applied the terms of "plucking" and "undercutting," seems discernible. Water action was certainly extensive, and whether it was in the form of subglacial streams moving in tunnels beneath the ice, or the floods emitted from its melting edges, or cataracts down its crevasses, the results are apparent in bedded sand layers. Engineer Chas. J. Bates has observed in the excavations for the Subway south of Fulton Street cross bedding in the sands, showing water reassortment (Fig. 55). It must be understood that when the Ice Age supervened, the surfaces of Manhattan Island were most variously weathered away, and it presented long ridges, scattered eminences, and generally presented an abrupt, short hill and valley structure; or, to use Dr. Gale's terminology, was an assemblage of "gneissoid islands."

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 10th 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.

Fig. 54. Pennsylvania Railroad excavation, 33d Street east of Seventh Avenue. Cavities made by removed boulders in the sand bank. June, 1901.

Fig. 55. Rapid Transit excavation in front of the City Hall, in sand, showing undisturbed bed of sand. June, 1901.

Fig. 56. Granite Boss, Bronx, showing glaciation.

Fig. 57. Glacial channels, Central Park, lower common, west entrance, 59th Street.

On 8th 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 débris investing Harlem plain, while it wrote its signature in furrows and scratches on the neighboring or bordering gneiss ledges. As far east as 3d and 2d 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 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 ten 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. 56). 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 southwest corner there (in Fig. 56 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.

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 furows, disappearing eastward, on a much weathered rock on the hilltop above the lake, north of the grove of Ginkgo 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 sand-papered 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. 57 and 58). The ice 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 center 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 inclosed 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. 59), 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. 60).

There need be no confusion in the mind of the observer between the glacial grooves, striæ 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, arise 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. 60 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 striæ. 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, 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. Professor 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 invariably find the surface of the hard crystalline rock smoothed and polished and all the projecting ledges worn and rounded off. This smoothed surface is also scratched and grooved in parallel lines, bearing usually N. 10° 15″ W. Upon this polished and striated surface rests an irregular confused accumulation of earth and stones from ten to twenty-five feet or more in thickness. This sheet of drift is spread over all the highlands, and, covering the hillsides, dips beneath the more recent sand dunes and salt marshes along the Newark Bay on the west, and bordering the New York Bay on the east. This drift consists mainly of broken and disintegrated red sandstone and shales derived from the Triassic area to the westward, and gives the prevailing reddish color to the soil. It also contains numerous boulders, frequently four or five feet in diameter; some of these are of

Fig. 58. Glacial Grooves and Glaciated Rock, Central Park, lower common, west entrance, 59th Street.

Fig. 59. Mt. Tom, Riverside Park and 83d Street, showing smooth glaciated dome, and at foot of the rock, glaciated grooves.

Fig. 60. Glaciated Rock-pinnacle in Riverside Park and 82d Street, showing glacial scratches and grooves crossing rock crevices.

Fig. 61. Sandstone boulder on top of Palisades, Englewood, N. J.

trap, doubtless derived from the hill itself; others are of metamorphosed slate, the parent beds of which probably overlie the trap on the western slope of the hill; with these are mingled many masses of Triassic sandstone that could only have come from the region covered by that formation to the westward. There are also other 'erratics' in less number composed of gneiss, quartzite, conglomerate, etc.—rocks that are found in place only in the highlands of New Jersey, at least thirty miles west." Fig. 61 shows a large sandstone boulder, an "erratic," brought to the edge of the Palisades, near Englewood, N. J. (C. J. Bates).

The drift material heaped up over lower New York on Manhattan Island has been alluded to in the accompanying paper on Topography and Rocks of New York City, and in the Inwood region, toward the Harlem, it is yet entirely evident. An interesting statement made by Dr. Gale in relation to the beginning of 4th Avenue can be profitably quoted: "4th Avenue commences at 14th Street, or at Union Square. The natural soil is, in this vicinity, fifteen or twenty feet above grading, and consists of drift, being an exceedingly confused mass of loam and gravel (rare) and boulders of immense size. Below grading in many places the drift loam continues some feet downward, say six to ten, when, if we do not reach rock, we find a fine sand, not generally white, but of dark gray, and often containing much mica and grains of hornblende, with quartz and feldspar predominating, and indicating that considerable portions of it had been the result of the disintegration of granite and gneiss."

Some years ago the superficial accumulations were removed from off the underlying rock at 80th Street and Broadway (Boulevard), preparatory to building. Fig. 62 shows the smoothed and ice-worn surfaces which doubtless, before they were scoured by the ice buffer, were irregularly weathered, pitted, and desquamate. Mr. H. Cleary, one of the engineers engaged in the work of preparing the foundations of the Hudson Terminal building, has described to the author the discovery of a large pot-hole, doubtless glacial in origin, on the northeast corner of the excavation for that structure, at the corner of Fulton and Church Streets. It was uncovered beneath the *hard pan,* and had been formed in the underlying schist. It had considerable dimensions, being seven feet in diameter, about five feet deep (?), and held at the bottom an accumulation of pebbles and mud.

Other evidences, more naturally referable to the consequences of the presence of the ice sheet, are found in rivers which, by reason of the glacial accumulations in the preglacial beds, have been diverted, or, as it were, ejected, and have been forced to find new channels. Such a remarkable fact seems proved by Professor J. K. Kemp within the limits of Greater New York and, in this case, illustrated by the Bronx and at a locality where a public reservation (Bronx Park) places it permanently within the observation of all.*

The gorge of the Bronx River, so strikingly shown a little southwest of the Lorillard House, has, it is assumed, been cut through the gneiss ridge at a time when it was compelled to desert a previous channel which passed southwest from Williamsbridge, and which approximately followed the line of the railroad track for some distance in the limestone beds in which its course north of Williamsbridge now runs. Pushed aside a little below Williamsbridge, it began its attack on the gneiss ridge to the southeast. Pot-holes west of the gorge, which have been excavated or bored in the rock by water running with some velocity and carrying sand or gravel, can yet be seen. Without dogmatizing, Professor Kemp suggests that the Bronx, as a preglacial stream was, upon the resumption of its duties with the passing away of the Ice Age, confronted by a drift bank filling up its old channel, and that it filed through the gneiss hill, cutting its way down as the land gradually rose. The photograph (Fig. 63) shows the west wall

*The teachers will find a comprehensive discussion and description of glacial grooves, etc., in the Seventh Annual Report of the United States Geological Survey, by T. C. Chamberlin.

at about its highest point, and exhibits a clean face of rock. Some initial work in the matter of opening this pass may have been accomplished by the glacier itself.

Teachers will find a wide and complete literature of the Ice Age. No subject seems to have been more thoroughly and repeatedly examined. In special treatises, in essays, lectures, and large compendiums, every aspect of this fascinating topic has received ample, almost tiresome, elucidation. Amongst the great number of possible books which might be mentioned, there are three essays of eminent value which can be consulted with profit and are readily found. These are T. C. Chamberlin's "Terminal Moraine of the Second Ice Sheet," in the Third Annual Report of the United States Geological Survey, Professor I. C. Russell's "Glaciers in the United States," and Professor Wright's "Ice Age in America." The information, suggestions, and illustrations in these works can be made most helpful in the teacher's efforts to explain to her pupils the "Evidences of Glaciation in and about New York."

PEAT IN POST-GLACIAL FORMATIONS

Among alterations of the surfaces, drainage changes, and superficial deposits, either marginal to the larger areas or accumulative in broader interior spaces, the growth and decay of vegetation at various points, in swamps, sink-holes, ponds, and marshes, has left within the city limits extensive peat beds. The very important morainal kettle (?) hole, drained and cleaned in the Moravian Cemetery on Staten Island (Richmond Borough), in which a mastodon's tooth was found, was littered with vegetable débris. Such material under favorable conditions becomes macerated, compressed, saturated with humus acids, and progressively altered, until a mass of porous, peat-like texture is formed, which is practically indestructible.

A very extended bed of this nature was uncovered in Centre Street during the preparatory work for building the loop Subway, connecting the East River and Williamsburg bridges. It was substantially vegetable residues, generally homogeneous, and inclosing in spots flattened twigs and small branches, while, in its upper layers roots, tendrils, and innumerable fibers appeared. It formed a brown body, deeply carbonized in black streaks, and drying to a board-like, leathery fabric, hard, feebly elastic, and tenacious. The accompanying diagram shows its distribution and thickness (furnished by the Degnon Construction Co.). It reached a depth of over forty feet in some sections, rested on clay, was covered by filling, and occupied saucers and pockets which may have been previously water-excavated gullies and basins. Mr. H. Cleary (assistant engineer) described the conditions as follows:

"The peat varies in depth (from 4 inches to 25 feet), and in composition depending upon its location in the pond. That in the Leonard Street area is deep (25 feet maximum), dense, brownish-black, fibrillous, and nearly homogeneous in texture, having a very slight odor, and appears to have been displaced by the gravel filling deposited upon it. That in the peripheral area at northerly and southerly limits of pond is shallower, fairly uniform (3 feet to 4 feet) in depth, and nearly level, is tan colored, odorless, dense, and fibrillous with horizontal lamination, containing roots, twigs, branches, leaves, and logs in a partial state of decomposition, but very compactly embedded in the peat. At northern area of pond many cedar stumps and roots *in situ* were found in a very slightly decomposed state, but compactly imbedded in the peat. The peat rested directly upon blue clay, into which the rootlets had freely penetrated and were visible passing into the sand below the clay in a flattened and decomposed state. The clay varies under the central and southerly areas of the pond from several feet to a few inches in depth, being uniformly about two feet thick under northerly pond area of tan colored peat.

"This pond was filled in during the years 1800 to 1834 to the level of the street surface. Mean water level stands at

Fig. 62. Ice-worn rock surface, 80th Street and Broadway, June, 1901.

Fig. 63. Section of Gneiss Ridge cut through by the Bronx River, Bronx Park.

Fig. 65. Iroquoian pot from the bank on south side of 214th Street near Tenth Avenue. Found by W. L. Calver.

about elevation 100, which is the level of mean high tide in the East and Hudson rivers at this point. The peat will consequently be submerged about ten feet at all times in the future, as it was when uncovered.

"The Map of Collect Pond is from Viel's Topographical Map of 1874. Profile and section are from observations taken during excavation and from soundings taken in trench to locate bottom of peat.

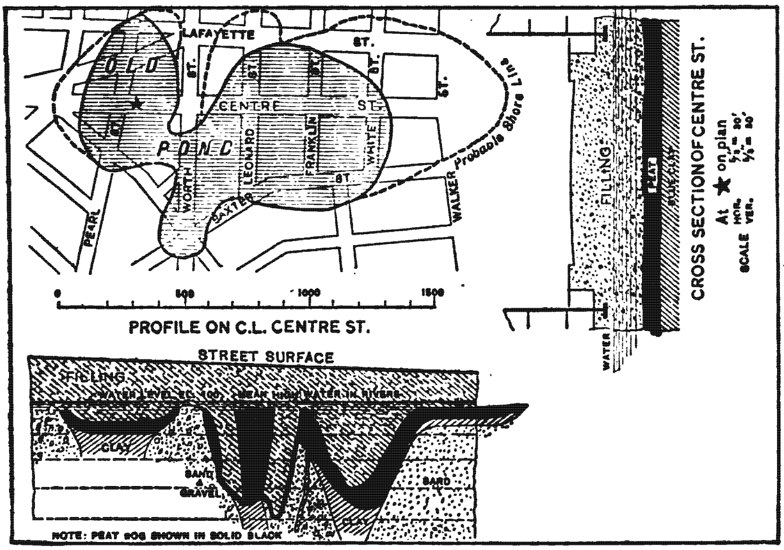


Fig. 64. Outline of section of the Centre Street Peat Bed.

"The northerly shore of the pond, as indicated by our excavations of peat in White, Walker, and Centre Streets, is indicated by dotted line on plan, marked probable shore line, and shows the pond extending two blocks further north than Viel's location."

The following note on the peat deposits in Brooklyn was contributed by Dr. Wallace Goold Levison, and forms a valuable record of these interesting formations:

THE PEAT BEDS OF PROSPECT PARK, BROOKLYN, N. Y.*

On Wednesday, February 7, and Thursday, February 8, 1867, I examined a series of peat beds which occupied certain depressions among a group of hills of drift material included within the area of Prospect Park, then in an incipient stage of construction in the City of Brooklyn, N. Y.

The highest of these hills, one near Flatbush Avenue, reached an altitude of 185 feet above tide level. Several other neighboring hills in the Park approached this elevation. The topography of this area was, however, subsequently changed somewhat in the course of construction of the Park. The entire area was originally covered with a forest growth, which had been removed with the exception of a few trees occupying the particular part of it in which the principal peat beds occurred, then known as the "Old Pigeon Ground."

Most of the neighboring depressions had bottom deposits of very impervious clay, evidently washed down by rains from the surrounding inclines, and over this a layer of peat in some cases still forming.

Four of these depressions contained peat in sufficient quantity to be regarded as "Peat Beds." Three of these occupied connecting valleys on the south side of Ninth Street, within a few hundred feet of Flatbush Avenue. These were filled in several years previous to my visit "to abate a nuisance," and Mr. Ludlam, then City Surveyor, thought that about ten feet of earth had been thrown over them. They had been reopened shortly before my visit in connection with the Park construction, and the top soil was found to be only about two feet in thickness. Under this the top layer of peat, about a foot in thickness, was penetrated in every direction by the roots.

The surface of the peat in the several beds had an average elevation of 139 feet above tide level.

* Levison (Wallace Goold), The Peat Beds of Prospect Park. Paper read before the Long Island Historical Society, February 27, 1867.

The fourth and principal Peat Bed occupied an enclosed basin north of 9th Street in the midst of the old "Pigeon Ground," and laid in the way of the proposed West Drive. It was found necessary to remove it entirely and refill the depression to the desired grade with a more solid material. Over 30,000 cubic yards of peat were removed from it.

This "Peat Bed," then called a "swamp," was of an elongated, indented oval form, 585 feet long, with a larger southerly and smaller northerly area. A line drawn through it about centrally lengthwise was 1,600 feet from Ninth Avenue and about parallel therewith. Therefore its length lay in a northeast and southwest direction. The larger southerly end reached within a few feet of the north side of Ninth Street and was 340 feet wide. The smaller northerly area was 140 feet wide. It was about twelve feet deep in the middle of its larger area and about four feet deep in the middle of its smaller area.

Its was surrounded and covered by a vigorous growth of large trees, the most prevalent being chestnut, white poplar, and oak. The older of these had usually about 90 annular rings. Those standing upon the peat had narrower rings and were of smaller diameter than those of like age standing upon the surrounding ground. The former had widely spreading roots, the latter deeply penetrating roots.

Dr. Wallace Goold Levison and Mr. Elias Lewis, Jr. (deceased), devoted a great deal of time in examinations of the geology and mineralogy, the superficial features and changes of Brooklyn and Long Island. Their papers were generally read at conferences of the Brooklyn Institute and before the Long Island Historical Society, but have never been published.

THE PRE-COLUMBIAN IN GREATER NEW YORK

When the white man reached the coasts of this New World he found it occupied by beings similar to himself. He may not, at the time, have sufficiently marveled at this, but his indifference to so singular a circumstance has to-day been replaced by the industrious researches of the archæologist, in an effort to trace the aboriginal record at every point of the continent. Whatever antecedent steps ushered the Indian to our eastern shores, it is very certain that when Hendrik Hudson entered the great harbor of Manhattan he had discovered the beauty and convenience of this inland bay.

The shores of the Hudson, the beaches, hills, and plains of Long Island, the islets, promontories, and woods of Manhattan Island, and the forested recesses and wave-splashed sands of Staten Island on the Raritan Bay were parts of his demesne, and furnished him with food, and offered him pleasant haunts for habitation and for pleasure.

Mr. Chas. B. Todd has given us an imaginative picture of Manhattan Island—the nucleus of the greater city—when the red man possessed it, and the white man first put foot upon it: "Nature's temples, not man's, adorned it. Sombre forests overhung the Jersey shore and fringed the water-line of the island. A chain of low, craggy hills covered with noble forests of oak, chestnut, hickory, and other trees, with pretty grassy valleys between, extended from the Battery to near the present line of Canal Street; on either side, along the river banks, were wide marshes stretching away to the north; at Canal Street they bore directly across the island, and were so low that on high tides the water flowed across from river to river. In the sheltered valleys were the maize fields and queer villages of the Indians and the rude log-cabins of the settlers who had come over the year before. Cow-paths crossed the marshes to the upper part of the island, which was much wilder and more savage, with precipitous ledges, and in many places dense thickets of grape-vines, creepers, blackberry and other bushes which no one could penetrate. The settlers did not allow their sheep and calves to cross this marsh lest they should be throttled by the wolves, bears, and panthers that lurked in the thickets, and in their letters home they complained of the deer and wild turkeys that broke in and destroyed their crops."

The Indians that lived in and around Greater New York at the beginning of the seventeenth century are described as "a branch of the great Algonkin-Lenapi family of aborigines," and are called the *Manhattos* or *Manhattans*. The Hackensacks and Raritans were on the west and south, the Weekqueskucks, Tankitikes, Packaniles, northward, and the Canarsees, Rockaways, Menikokes, Massapeagues, Mattinecocks, Missaqueges, Conchaugs, Secatauges, and Shinnecocks are given by Todd as their Long Island neighbors. Again, north of all were the more formidable Mohawks and Mohicans. Mr. Edward Manning Ruttenber tells us that Hudson met the Wappingers or Wapanachki, and they were of the sub-tribe of the Reckgawawanes. He further narrates: "The point of land from which their attacks were precipitated was on the north shore of the Papiriniwen, or Spuyten Duyvil Creek, where their castle or palisaded village, called by them Nipinichan, was located. This castle commanded the approach of their inland territory from the Mahicanituck on the south, while a similarly fortified village at Yonkers, at the mouth of the Neparah, or Sawmill Creek, and known as Nappeckamak, commanded the approaches on the north. Their territorial jurisdiction extended on the east to the Bronx and East Rivers, and on the south included Manhattan Island, which, however, was only temporarily occupied during the seasons of planting and fishing, their huts there constituting their summer seaside resorts, and remaining unoccupied during the winter."

The succession of the sub-tribal organizations, given by Ruttenber to the north and east of Manhattan, were the Weckquaesgecks, the Sint-Sinks, the Tankitekes, the Kitchawongs. On the east were the Siwanoys and the Sequins. The Siwanoys "extended from Hell Gate twenty-four miles east along the Sound to Norwalk, Connecticut, and thirty miles into the interior." The Weckquaesgecks had a village near

Dobb's Ferry. The name Manhattan, as applied to New York Island, was given by the Dutch, not by the Indians. The following extended extract is from Mr. Ruttenber's excellent paper on "The Native Inhabitants of Manhattan," in the Memorial History of the City of New York:

"Kapsee is the Indian name of the extreme point of land between the Hudson and East Rivers, and is still known as Copsie Point. It is said to signify 'safe place of landing,' as it may have been, but *ee* should have been written *ick*. The Dutch called it Capsey Hoeck; they erected a 'hand,' or guide-board, to indicate that all vessels under fifty tons were to anchor between that point and the 'hand,' or guide-board, which stood opposite the 'Stadtherberg,' built in 1642. This indicates that the point had the peculiarity which is held to be expressed in the Indian name. Sappokanikan, a point of land on the Hudson below Greenwich Street, has been explained as indicating 'the carrying place,' the presumption being that the Indians at that place carried their canoes over and across the island to East River, to save the trouble of paddling down to Kapsee Point and from thence up the East River. This explanation is, however, too limited. It was from this point that the Indians crossed the river to Hobokan-Hacking, subsequently known as Pavonia, now in Jersey City, and maintained between the two points a commercial route. Lapinikan, an Indian village or collection of huts which was located here, had, no doubt, some special connection with the convenience of the Indian travelers. Corlear's Hook was called Naig-ianac, literally 'sand lands.' It may, however, have been the name of the Indian village which stood there, and was in temporary occupation. It was to this village that a considerable number of Indians retreated from savage foes in February, 1643, and were there massacred by the Dutch. Near Chatham Square was an eminence called Warpoes—*wa* singular, *oes* small—literally a 'small hill.' Another hill, at the corner of Charlton and Varick Streets, was called *Ishpatinau*—literally a 'bad hill,' or one having some faulty peculiarity, *ish* being the qualifying term. *Ishibic* probably correctly described the narrow ridge or ancient cliff north of Beekman Street, to which it was applied. *Acitoc* is given as the name for the height of land in Broadway, *Abic,* as that of a rock rising up in the Battery, and *Penabic,* 'the comb mountains,' as that of Mount Washington. A tract of meadow-land on the north end of the island, near Kingsbridge, was called Muscoota, which is said to signify 'grass land,' but, as the same name is given to Harlem River, other signification is implied, unless, in the latter case, the word should be rendered 'the river of the grass lands.' A similar dual application of name appears in Papirinimen, which is given as that of a tract of land 'on the north end of the island,' about One Hundred and Twenty-eighth Street, between the Spuyten Duyvil and the Harlem, and also as that of the Spuyten Duyvil. Shorackappock is said to have described the junction of the Spuyten Duyvil and the Hudson, but the equivalents of the term—*sho* and *acka*—indicate that the interpretation should be, as in Shotag (now Schodac), 'the fire-place,' or place at which the council chamber of the chieftaincy was held—an interpretation which clothes the locality with an interest of more significance than the occurrence there of the attack upon the Half-Moon. The island was intersected by Indian paths, the principal one of which ran north from the Battery or Kapsee Point to City Hall Park, where it was crossed by one which ran west to the village of *Lapinikan,* and east to *Naig-in-nac,* or Corlear's Hook. The name assigned to the village, *Lapinikan,* may have been that of this crossing path, which was continued from Pavonia south of the *Lenapewihitaik,* or Delaware River. Many of the ancient roads followed the primary Indian foot-paths.

"The aboriginal names of the islands in the harbor have been preserved more or less perfectly. Staten Island is called, in the deed to De Vries, in 1636, *Monacknong;* in the deed to Capellen, in 1655, *Ehquaous,* and in that to Governor Lovelace, in 1670, *Aquehonga-Manacknong,* titles which are presumed to have covered the portions owned by the Raritans and Hackinsacks, respectively. The names in the deeds to De Vries and Capellen, however, are but another orthography of those in the deed to Lovelace. *Manacknong* signifying 'good land,' in a general sense, may be accepted as the aboriginal name. Governor's Island was called by the Dutch Nooten Island, 'because excellent nut trees grew there,' and possibly, also from Pecanne, the Algonquin term for nut trees. Bedloe's Island was called *Minnisais,* a pure Algonquin term for 'small island.' It does not appear to have possessed a qualifying character of any kind. Ellis Island was *Kioshk,* or Gull Island, and that of Blackwell's was Minnahonnonck, a phrase that is not without poetic elements, but has none in this connexion, *minna* being simply 'good.' In its vicinity is Hell Gate, to which *Monatun* has been applied—'a word,' says an eminent authority, 'carrying in its multiplied forms the various meanings of violent, dangerous, etc.,' in which sense it may be accepted. The name of Long Island is sometimes written *Sewan-hacky,* from *sewan,* its shell money, and *acky,* land; but its aboriginal title appears to have been *Matonnacky,* —*ma,* large, excellent, *acky* or *acke,* land."

The proximity of the ocean with its products attracted the aboriginal inhabitants, and village sites doubtless occupied its more accessible and inviting margins. Such have been found on Long Island by Mr. R. Harrington, while very large collections of stone hammers, fleshers, arrow points, adzes, etc., have been made, among which that of Mr. William W. Tooker, of Sag Harbor, was perhaps pre-eminent. On Staten Island Indian implements and Indian graves have been discovered, the centers of occupancy being generally west and southwest; at Mariners Harbor on the north, and Tottenville on the south. William T. Davis, George H. Pepper, and Allanson Skinner have contributed to the archæological exploration and knowledge of this region.

On Manhattan Island the better established areas of occupation seem to be around Inwood, though tradition affirms the use of the present City Hall Park by the Indians for an encampment. Fig. 65 illustrates a most interesting find of a pre-Columbian pot on Manhattan Island.

Mr. Reginald Pelham Bolton has furnished the following notes on the Archæology of Manhattan Island:

"No other portion of our country is richer in archæological remains than the upper end of the island of Manhattan, now know as Washington Heights. It was the specially prized hunting ground and residence of the Wick-quas-keek clan of aborigines, the home of a number of the best known of the patentees of the Township of New Harlem, of which it formed a part, the scene of a number of military engagements in the war of the Revolution, including the assault and capture of Fort Washington (Nov. 16th, 1776), and the camping-ground of thousands of Hessian and British troops until 1783. It has only been developed within a very recent period, and much of the material which is now being found has thus been preserved.

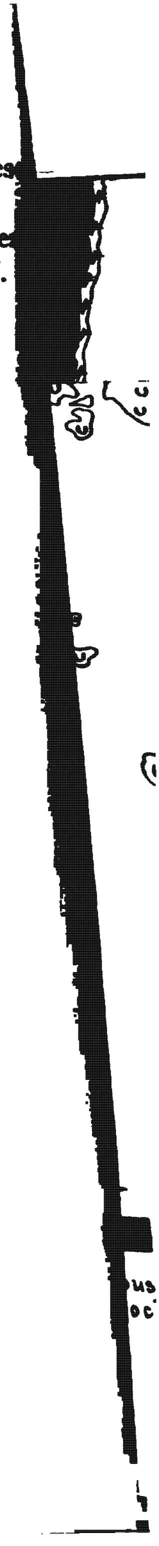
"The Indian remains are numerous; they include considerable shell heaps, a number of shell pits, below which have been found burials of men, dogs, snakes, fish, and turtles, many surface finds of implements, ceremonials, and evidences of manufacture of arrow and spear heads.

"The Colonial remains have been found around the sites of old Dutch homesteads, in the Inwood valley, chiefly those of the Nagel and Dyckman families. Pewter, pottery, pipes, coins, household utensils, and other objects have afforded quite an insight into the domestic life of the Dutch and Early English periods of occupancy of the region.

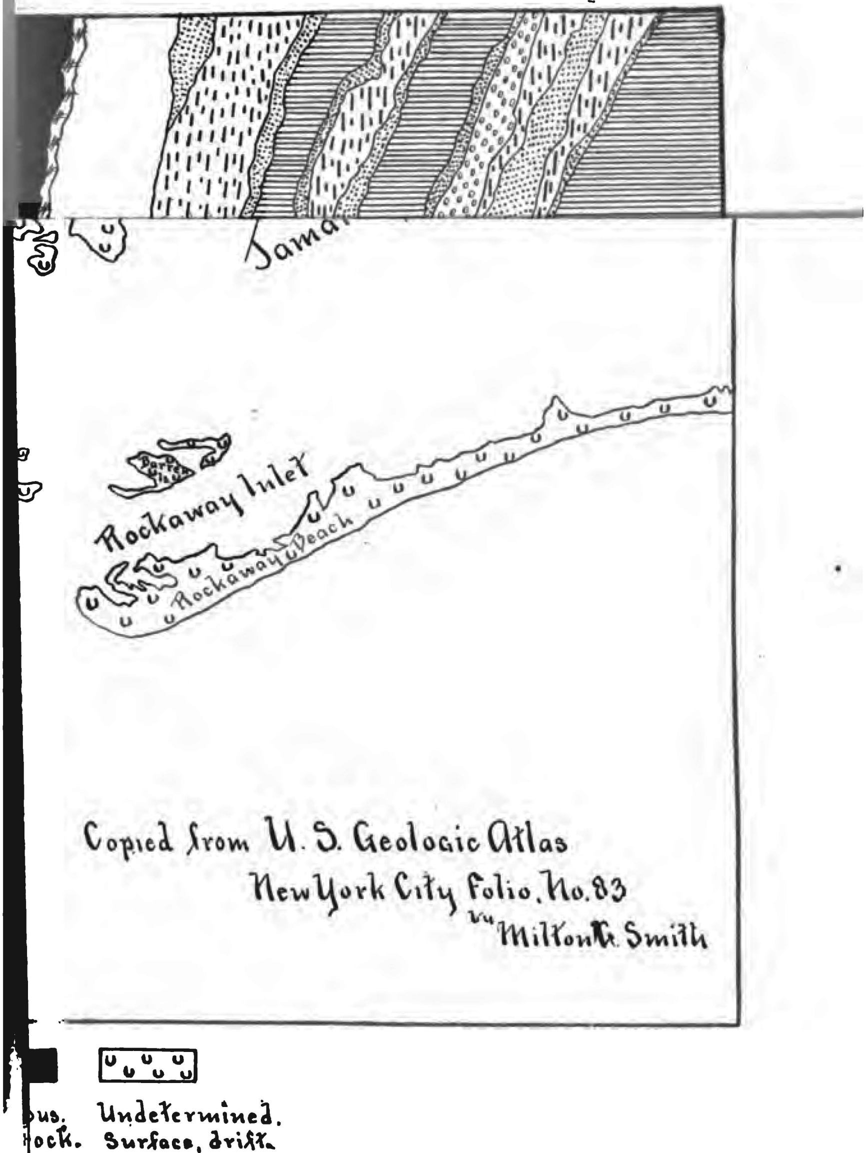
"In military remains the region is particularly rich. The numbered buttons of nearly all the regimental corps of the British army engaged in the Revolution have been found, with accoutrements, weapons, and missiles of great historical interest and value. The habits and life of the soldiery have been traced by the remains of their food, utensils, pikes, cutlery,

and their huts and fire-places have located their pres
certain camp sites of considerable interest.

"A collection of these objects, covering the three pe
historical transactions, has been formed by Messrs. W.
ver and R. P. Bolton."



MAP IV



Rockaway Inlet
Rockaway Beach
Copied from U. S. Geologic Atlas
New York City Folio, No. 83
Milton R. Smith
Undetermined.
Surface, drift.

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