THE

GEOLOGICAL HISTORY

OF THE

PASSAIC FALLS

Paterson New Jersey

BY WILLIAM NELSON

PATERSON, N. J.:
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1892.

The Passaic Falls are the most remarkable bit of natural scenery in New Jersey.

In some respects they are unique.

For more than two centuries they have been visited by travelers from all parts of the world.

Their peculiar formation, and the strange rocks in the neighborhood, have excited the wonder and curiosity of all beholders, and have often suggested the thought, "How was this cataract formed? Why these peculiar rocks and mountains?"

In preparing a History of the City of Paterson—a city which was located at the Great Falls to take advantage of the water-power—the writer's attention was naturally directed to the question which has arisen in the minds of all who have stood at the spot where the Passaic river takes its mad plunge over the precipice.

In the following pages he has attempted an answer, by giving some account of the Geological History of the Passaic Falls.

This paper is the first Chapter of the more extended History of Paterson mentioned. Only one hundred copies have been printed separately in this form. The writer will be pleased to receive suggestions and corrections from any who may receive a copy of this pamphlet.

The references and notes have been made full, as a guide to those unfamiliar with the subject, who may wish to pursue it further.

PATERSON, N. J., November 24, 1892.

Geological History

OF THE

Passaic Falls.

> "At His word, the formless mass,
> This world's material mould, came to a heap:
> Confusion heard His voice, and wild uproar
> Stood ruled, stood vast infinitude confined;
> Till, at his second bidding, darkness fled,
> Light shone, and order from disorder sprung."—*Milton.*

> "This world speaks plain for who has ears to hear."—*Goethe.*

"IN THE BEGINNING GOD created the heaven and the earth.

A huge molten globe at a white heat, flashing out light in all directions like a great sun, and whirling through space with an inconceivable velocity, but still held in place by a mysterious law which at the same time repelled it from and yet held it by unbreakable bonds within the attraction of gravity to the greater sun, of whose system it still formed a part, although no longer a portion of its integral substance. And so through countless ages coursing on in its fixed path, its white heat creating an atmosphere of its own which gradually absorbed more and more of its fierce fires, until millions and hundreds of millions of years as we count time had elapsed, ere that white heat had subsided to a fiery red, and that to a dull glow, and at last a blackened mass appeared instead of that flaming ball, as the surface particles subsided into comparative quiet, and the original fires shrank further and further into the recesses of the planet that we call the Earth.[1] Five hundred million times had this fiery ball circled about the central sun of its system ere it parted with enough of its heat to permit its surface to cool and become hardened into the earth's crust. Millions of times more it sped on in its orbit, while its outer surface, through the alternate contraction and expansion of heat, rose here and fell there.[2] The condensing vapors sank into the depressions and formed oceans, and the more considerable elevations rose above the surrounding waters and formed lonely islands in the vast waste, islands destined to become lofty peaks in the mountain chains that were to rise above the continents yet unformed. The atmosphere, which through many millions of years had been absorbing the substance of the molten planet lying nearest the surface, and hence was heavily charged with all the component parts of the earth, as it became changed into water retained the elements of the minerals which had once been fused into one liquid mass, and the seventy or eighty materials of which all rocks are formed. The water was still at a boiling heat, and as these materials were dropped on the shores of the vast oceans, especially at the bases of the solitary islands, the deposits were fused into crystalline rocks. The islands grew larger and larger, as the cooling of the earth's surface went on, and

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1 See Herbert Spencer's Essay on the Nebular Hypothesis of Laplace, in Illustrations of Universal Progress, New York, 1865, p. 239. (A new and revised edition was published in 1892.) Herbert Spencer's First Principles (second edition), New York, 1871, pp. 203–8, 382–6. Humboldt's Cosmos, New York, 1873, IV., 20–21. A poetic conception of the Nebular Hypothesis, with some startling conclusions, is presented in Eureka: a Prose Poem, by Edgar A. Poe, New York, 1848. [The writer's copy has numerous manuscript corrections and interlineations, in Poe's handwriting.] "The Chemical History of the Six Days of Creation," by John Phin, C. E., New York, 1870, presents in very compact form the operation of chemical forces in the earth's creation.

2 "Professor Helmholtz has calculated from the rate of cooling of lava, that the earth, in passing from 2,000° C. to 200° C., must have taken three hundred and fifty millions of years. But the temperature when the Archæan period ended was probably not over 38° C. (100° Fah.), to reach which many scores of millions of years must have been passed. *The era was long.*"—*Dana's Geology*, *third edition* (1880), p. 149, note.

there was more contraction and elevation, and these peaks, with their accretions of ocean-made rocks, became elevated into the incipient Appalachian and Rocky Mountain chains. Through a tract thirty miles wide in Northern New Jersey, and very abundantly in the northern part of Passaic county, may be seen rocks deposited in those Archæan times—gneiss, schist, mica and granite.[1]

While the work of constructing the continent was going on a work of destruction had already begun, and the mighty waves of boiling water dashing again and again against the obtrusive rocks which had dared to lift their heads above the dreary wastes, crumbled and broke these rocks into many fragments, pulverized them into sand, and carried the particles to other places to form new portions of the future continent, until, in the course of countless ages, this debris was piled up in many places to a depth of from thirty to forty or fifty thousand feet, all in level beds, stratum upon stratum, to form the layers of granite, gneiss, mica, quartz, syenite and schist that in general compose the Archæan rocks.[2] With the alternations of the earth's surface from time to time these level beds were upturned, bent,

[1] Investigations under the direction of the New Jersey State Geological Survey in the Summer and Fall of 1891, indicated that the granite which appears in the limestone region of Sussex county, near the northern boundary of Passaic county, is of eruptive origin, having forced its way from lower strata, and that the heat communicated from its molten state has transformed the blue limestone prevailing in that region into white limestone, and sometimes into marble. See Report of the State Geologist for 1891.

[2] Many attempts have been made to classify these Archæan rocks. In the Report of the State Geologist of New Jersey for 1886 (p. 77) it was proposed to arrange them in three groups: I. Massive Group; II. Iron (Magnetite) Bearing Group; III. Gneissic and Schistose Group. But in the Annual Report for 1889 (pp. 29-32) this classification was abandoned, and it was proposed to arrange them in four types, according to the character of the rocks, naming them, provisionally, from the locality in which the rock prominently occurs—Mount Hope, Oxford, Franklin and Montville. The Archæan series of New Jersey corresponds generally in the character of the rocks with the Laurentian system of Canada. These rocks cover 900 square miles in Northern New Jersey; the belt is from ten to twenty miles wide, and crosses the State in the general direction of N. 50° E; the strike of the rock (the direction of the upturned and exposed edges of the strata) is about N. 53° E.—*Annual Report*, 1873, *pp.* 11-15.

broken and displaced. The ocean was still at work rock-making, in which it was aided by the vast amount of carbonic acid gas in the atmosphere. The old sedimentary beds of limestone became crystallized into granite, gneiss, syenite, etc., while the layers of clay accompanying iron ore were transformed into schist and quartz. Now sandstone was deposited and consolidated—deposited in the form of loose sand, and became consolidated into rocks, and North America slowly emerged from the waste of waters with something of its present outlines. The ocean pressed from the east and southeast against the new-formed land and crumbled the emerged rocks, and casting out from its own depths the accumulation therein deposited formed beaches along the shores of the primeval continent.

An awful silence brooded over the virgin earth. There were no sounds. Had there been, there was no living thing to hear them. But in time the ocean began to teem with minute creatures whose shell homes were gathered up by the waters and deposited to form more limestone. The Highlands of New Jersey were islands or reefs in the sea, and checked the flow of the ocean over the interior continent, still largely covered by waters.

Another period of uplifting and upturning began. New rocks were formed and piled up by the action of sea and air to a thickness of twelve thousand feet, and the earth gradually subsided to that depth under these vast accumulations of new material. Along the Hudson river, and perhaps in Northern New Jersey at the same time, a new deposit of limestone was made, to a thickness of four hundred feet, formed by the ocean grinding up the accumulation of shells within its limits. The continent still rose and fell as the bosom of Mother Earth heaved with the pulsations of the new life, and again the strata of the rocks were bent into arches and bold flexures, particularly in the regions north of New Jersey.

"And God said, Let the earth put forth grass, herb yielding seed, and fruit tree bearing fruit after its kind, wherein is the seed thereof, upon the earth: and it was so."[1] The

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1 Genesis I, 11, Revised Version.

monotonous white beaches were strewed with green sea weed, while in the interior a small ground pine tree arose above the earth. The warm and temperate seas that stretched from pole to pole were the only waters yet existing, and the only living creatures within them were shell-fish.

Another age now dawned upon the earth. Again the ocean was engaged in rock-making—sandstone or gritty shale, particularly in the Appalachian ridge. Fishes now first appeared, of the shark tribe, and other fish, some of them ten or twelve feet long, formidable creatures armed with horns. Trees in abundant verdure covered the earth in forests and great jungles, over vast marshes. A shallow sea covered much of New York and New Jersey, and as the earth subsided, layer upon layer of sandstone and other formations was deposited, as the earth sank slowly beneath the waters. Rocky islands loomed up here and there, where are now the lofty Appalachian mountains. The continent was covered with forests and marshes, vegetation subjected at long intervals to inundations of fresh or marine waters. The vegetation became less, as the sea rose again over much of the continent. There was a new era of the making of sandstone, while limestone was formed in the interior. The air was still surcharged with carbonic acid gas, hostile to the higher forms of life, but affording nurture to the rank vegetation that everywhere prevailed. As the growth in the marshes and jungles absorbed the carbon, storing it away for the use of man, who as yet was unknown, these beds of decaying vegetation sank again beneath the level of the sea, to have deposited on them sandstone and slate, and here and there layers of iron ore, then to rise again and receive new accumulations of vegetation, absorbing again the carbonic acid gas in the air, to sink once more and be covered as before, and so on and on for untold ages, until the first beds of anthracite and bituminous coal were formed throughout the world. These jungles were the homes of reptiles that now appeared upon the earth—huge snakes, monstrous saurians, turtles and the like.

Again the whole earth was submerged beneath the ocean. An Artesian well has been sunk at Atlantic City on the New Jersey coast to a depth of fourteen hundred feet, without reaching the Archæan rocks below. The clay at the bottom of this well is full of fossil foraminifera, indicating that it was deposited at a time when the ocean was teeming with life, though of a low order.[1] It has been estimated that the New Jersey coast is sinking at the rate of one or two feet in a century.[2] If this rate has continued from the time that this foraminiferous clay was deposited, from seventy to one hundred and forty thousand years must have elapsed since the clay at the bottom of this well was washed by the ocean waves. The thickness of the rocks deposited during the Palæozoic time was fifty-five thousand feet. At the rate of a foot a century, this must have taken more than five million years to accumulate. When it is considered that during this time there were such frequent alternations of elevation and depression of the earth's crust, it is evident that this estimate in years is far below the mark. During the Palæozoic ages the New Jersey Highlands became prominent, and the first rivers on the new continent appeared—the Hudson, St. Lawrence and Connecticut. During the last of this period seven miles of subsidence took place along the Appalachian region, and elevations and depressions of the earth altered the character of the strata, turned the soft beds of coal into anthracite, while older rocks were changed to gneiss, mica, schist, slate and marble. As the earth became elevated the fury of the ocean became greater, and beat with increased power upon the shores of the continent once more rising from its fierce embrace.

The Palæozoic age was succeeded by the Mesozoic, ushered in by the Triassic period. Now the present sandstone was deposited, as the ocean slowly washed away the granite and gneiss of the Archæan ranges, and converted the

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[1] Reports by Lewis Woolman on Artesian Wells at Atlantic City, in Annual Reports of State Geologist, 1889 and 1890, and in Proceedings of the Academy of Natural Sciences, Philadelphia, March 25, 1890. In the last-named publication Mr. Woolman gives a list of 149 species of diatoms found in the clay, from 383 to 658 feet below the surface.

[2] Geology of New Jersey, 1868, p. 362; Annual Report for 1881, p. 31.

rocks into sand, which in process of time, by the action of the elements, became solidified into strata of stone. Thus there was formed a belt of sandstone, from ten to thirty miles wide, along the base of the Appalachian range, from Nova Scotia to South Carolina. In New Jersey the Triassic belt is about twenty miles wide, extending across the State from the Hudson to the Delaware, covering an area of fifteen hundred and forty-three square miles. The sandstone and shale are all in uniform layers, with a prevailing dip toward the Northwest. At Paterson, however, the dip of the sandstone in the quarries at Garret Mountain is N. 80 degrees W., and the amount of dip is 10 degrees; at Beattie's quarry, at Little Falls, the direction of the dip is N. 50 degrees W., and the amount is the same as at Paterson, 10 degrees. Fossil bird-tracks and water-pittings found in the rocks near Pompton, and limestone pebbles found in the same beds at Paterson,[1] show that the sandstone is of sedimentary origin, even if we did not see the same kind of rock in process of formation at most lake shores to-day. Not only were there great birds on the earth at this time, and monstrous lizards and other reptiles, from ten to forty feet long, but the earliest types of mammals appeared also. The vegetation covering the land consisted largely of cone-bearing trees, a distinct species of which existed in this vicinity, fossil specimens having been found at Little Falls. The deposition of these beds of sandstone and shale went on for ages, the earth gradually sinking under the mighty mass, until perhaps five or six miles in thickness had been formed.[2] As the sandstone beds were deposited upon the irregular hills and mountains of Archæan rocks beneath the waters of the ocean, they

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[1] Fossils found in the sandstone quarries at Belleville in 1879 and since, seem to indicate that the formation belongs to the Upper Carboniferous, if not to an older period.—*Annual Report N. J. State Geologist*, 1879, p. 27.

[2] By observing the angle of dip at various points, and the out-cropping ends of the beds of sandstone, it is calculated that the formation must be at least 27,000 feet thick. The greatest depth (2,100 feet) ever reached in the sandstone was found in boring the artesian well at the Passaic Rolling Mill, at Paterson, in 1879-80. A detailed account of this well is given at the end of this paper.

gradually subsided; the older rocks were probably rising at the same time; these being vastly harder than the other, the beds of sandstone bent, and finally broke here and there in lines parallel with the Archæan ranges.[1] In many places one part of the bed went on sinking down the side of the granite hills, while the other portion of the bed remained stationary, and thus there was formed what geologists call a "fault" in the rock. Taking a comprehensive view of the earth's surface in the vicinity of Paterson at this period, we may imagine a horizontal bed of sandstone extending at the same general level from New Brunswick or Princeton northeasterly to the present New York State line, and from the Hudson river twenty or thirty miles westerly to the present Archæan range. This is the sandstone now found in the quarries of Middlesex, Union, Somerset, Essex, Passaic and Bergen counties. We may imagine this sandstone bed gradually subsiding, and, in the neighborhood of Paterson, and along a line extending southeasterly for forty miles, resting upon a mass of rounded Archæan rock; the increasing weight of the ever-accumulating beds above gradually forced the sandstone to bend on each side of the immovable line below; it kept on bending until the breaking point was reached; then there was a fracture; the rock to the east and southeast slid down further, while the edge of the rock to the west of the breaking line rose, forming a cliff, two, three or four hundred feet higher than the adjacent sandstone beds, and facing toward the east and southeast. The quarrying operations on the face of Garret Mountain show that there the sandstone has a height of three hundred feet above the sea; the sandstone under Morris Mountain, and that in and near the Valley of the Rocks, at Riverside and at other points in Paterson, is only from fifty to one hundred feet above tide-water. At Passaic, in the western part of the city, the sandstone is found at a depth of from thirty to sixty feet below the surface, or but little above tide level, while in the eastern sec-

[1] There is strong reason for believing that some mighty external force was exerted on both the sandstone and the Archæan rocks to effect this deformation; many geologists believe it was the power of the ocean, exerted from the east and southeast.

tion the sandstone is from one hundred to one hundred and twenty-five feet below the surface, or from eighty to one hundred feet below the level of the sea. This marked difference in the position of the adjacent beds of sandstone certainly indicates a remarkable tilting in these beds, and probably a "fault" somewhere in this neighborhood, which might be caused in the manner described.

While these sandstone beds were being formed, and in many cases while they were still in a plastic state, a strange thing happened. Up through fissures which extended down to the fiery interior of the earth, there poured forth a mass of molten rock, of a new kind, which we call "trap." This fluid rock penetrated between the layers of the sandstone in all directions, separating the beds widely. Every fissure, every opening, was thus filled with red hot lava, and wherever there was loose earth, or beds of broken shale beneath the beds of sandstone, this liquid mass found its way. Strangely enough, this igneous eruption appears to have been of the same character throughout the Triassic formation, from Nova Scotia to North Carolina, and is seldom found elsewhere. In New Jersey it covers an area of about three hundred and thirty square miles. The peculiarity of this formation has attracted the attention of geologists for more than half a century, and fully seventy writers have written nearly two hundred articles in attempting to elucidate the subject.[1] The beds of trap ap-

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[1] It may be remarked here that while the igneous origin of the trap rock has been accepted as a fact by geologists, with few exceptions, Professor Henry Wurtz, of Hoboken, a distinguished chemist, was at one time inclined to believe that possibly it might be shown on further investigation that the trap was a metamorphic rock, and was formed *in situ*. In other words, that the sandstone upon which the trap rock is invariably found to be superimposed, has undergone a chemical change into trap rock, and that this change is still in progress. The writer had noticed that on the side of Morris Mountain, there was a point where it was difficult to tell where the sandstone ended and the trap rock began, and in 1872 he pointed this out to Professor Wurtz, who regarded it as a striking confirmation of his conjecture that the trap rock was chemically-transformed sandstone. So far as the writer is aware, although he had some subsequent correspondence with Professor Wurtz on this subject, the Professor never concluded his contemplated experiments to determine whether or not his conjecture was demonstrably

pear in bands of from three inches to several hundred feet in thickness. The adjacent sandstone was baked into hard grit, while the steam accompanying or generated by the eruption gave the lava in many places the appearance of volcanic scoriæ or cinders, or turned it into bosses and rounded masses like fused boulders. The most striking instances of this were formerly to be seen on Marion street, between Totowa and Union avenues; the rock appeared to have been a mass of boulders, fused together by the action of fire and water, the form of each boulder-like boss or rounded mass distinctly shown by the lines of the green carbonates of copper permeating the whole.[1] Occasionally the trap rock is divided by planes, parallel to the bedding, the texture of the rock above and below such planes of separation differing slightly, indicating that the rock was deposited by successive eruptions, each bed having time to cool before a new overflow occurred. Frequently cavities were formed in the hastily-cooled lava, and the steam or hot vapors caused these cavities to be filled with prehnite and other beautiful crystals, white, yellow or purple in color. In some places—as at Morris Mountain in Paterson, on the south side of the river, near Little Falls, and in a quarry at Orange—the later outflows of lava have assumed a prismatic or columnar form,[2] like the basaltic columns at

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correct. It was a bold conception quite characteristic of Prof. Wurtz, who was an original thinker. Of late years the microscope has come into use in testing doubtful rocks, and by this means it has been determined beyond a doubt just where is the line of demarcation between the trap and the sandstone, and that there has been no fusion between them, and no chemical metamorphosis of one into the other. The curious reader may find a presentation of Prof. Wurtz's idea in the Proceedings N. Y. Lyceum, Vol. I., 1871.

[1] This rock, formerly ten feet above the level of the street, has been blasted out and removed for use as road material; the quarry is now eight or ten feet below the surface of the street. It is softer than most trap rocks, and packs more readily. This quarry has been a favorite resort of mineralogists for years, and great quantities of most beautiful specimens thence now enrich the cabinets of institutions and of private collectors.

[2] A lithographic view of the columnar formation near Little Falls is given in the Annual Report of the State Geologist, 1882, page 53; the lithographic frontispiece to the Annual Report for 1884 gives three

the Giant's Causeway in Ireland. At Morris Mountain the trap rock overlies the sandstone in a horizontal bed twenty-five feet thick, and above this rises the columnar formation to a height of fifty feet.[1] It has been conjectured[2] that as the fiery mass came up from the bowels of the earth, it passed through beds[3] of iron ore and of copper, bringing up copper in the form of green carbonates and sulphides, and iron as oxides, which became disseminated like vapor through the rocks, the oxide of iron coloring the sandstone red. But Professor William Morris Davis, of Harvard University, who has studied the red sandstone and trap formations in and about Paterson for the last ten years or more, with great care, in a letter to the author says "there is little ground for this belief, and many facts militate against it. Sandstones remote from volcanic or igneous rocks are often red, and on the other hand many sandstones near such rocks are not red. Moreover, the sandstones overlying the last trap overflow are not less red than those below." It is difficult to believe that the sandstone at Paterson should have been colored in the manner suggested to the depth of two thousand feet, as at the artesian well at the Passaic Rolling Mill; and it seems improbable that the coloring of this formation should have been thus produced so uniformly throughout its fifteen

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views of the basaltic columns at Orange. This tendency to a basaltic or columnar formation at the Passaic Falls was noticed as long ago as 1819, by Samuel Akerly, in his "Geology of the Hudson River, and the adjacent regions: illustrated by a Geological Section of the Country, from the neighbourhood of Sandy Hook, in New-Jersey, northward, through the Highlands in New-York, towards the Catskill Mountains." New York: 1820, p. 34.

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1 This hill is being fast carried away for road material. A view of the hill as it appeared in 1868 is published in the Geology of New Jersey, 1868, p. 103.

2 Geology of N. J., 1868, p. 338.

3 There are no true veins of iron ore in New Jersey; the ore is always found in beds, indicating a sedimentary origin. The beds, however, have been usually so turned up in folds as to give them the appearance of veins.

hundred square miles of area. In a quarry near Haledon [1] the red sandstone is underlaid by a bed of sandstone nearly white. If the lava outflow was instrumental in dyeing the upper stratum red, why not this lower stratum also? On the whole, it is more reasonable to assume that the red color of the sandstone is an original characteristic as the sediment was deposited. Why it is red is as yet little understood. The same may be said as to the origin of the traces of copper in the trap rock. It is certain that the indications of copper were strikingly marked in the trap rock at Marion street; they have been noticed elsewhere along the First Mountain, and have led sanguine people to believe that untold wealth in the shape of copper lay beneath these rugged hills. The Palisades, First Mountain, Second Mountain and Preakness Mountain, or Black Oak Ridge, are all of this trap rock formation, now overlying the red sandstone; traces of a fourth ridge have been discovered within a few years. All these ridges are parallel, and all have a crescent form, somewhat roughly corresponding to the general trend of the chains of Archæan rocks to the northwest. The First Mountain, of which Garret Mountain is a conspicuous part, apparently began at Sicomac, beyond High Mountain, and extends southwesterly forty-three miles to Pluckamin, in Somerset county, its crest running uniformly from four hundred and fifty to five hundred and fifty feet in height, the even crest being broken by a few depressions, and some peaks rising to a height of between six hundred and seven hundred feet. The Second Mountain extends from Pompton on the north, southeasterly by way of High Mountain, and thence southwesterly to Mount Horeb, Somerset county, with an inward westerly

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[1] On the upper High Mountain road, about a mile north of Haledon. First there is a layer of earth, about two feet; then trap rock, thirty feet; then two beds of red (or brown) sandstone, one lighter in color than the other, the two having a total thickness of about twenty-five feet; then red shale, four feet, and then a bed of sandstone, light buff in color, closely resembling Ohio sandstone. This last layer has been opened for ten or fifteen feet, but its depth has not been ascertained. This quarry was worked as long ago as 1815, by Capt. John Anderson; it is now (1892) owned by the New Jersey Brownstone Company.

curve to Bernardsville. The height of its crest varies but little from five hundred and fifty feet, except at the few gaps, and at such exceptional peaks as High Mountain (878 feet) and at Caldwell (684 feet). The Third Mountain runs like the letter ꭥ laid horizontally, from Pompton to Mountain View, Montville and Pine Brook, the height being from three hundred and fifty to four hundred and fifty feet. The Palisades tower up in stately grandeur above the Hudson five hundred and twenty feet near the New York State line, gradually diminishing in height, to disappear at Bergen Point, perhaps to reappear in the short trap ridge at Rocky Hill.[1] The Palisades and the First and Second Mountains terminate in hooks, turning inwards, or westerly, toward the concave side.[2] These hooks are believed by Darton[3] to be entirely due to flexures of the rocks.[4] Prof. Davis says "the cause of the curved trend of the trap ridges is sufficiently found in the unequal uplift of different parts and subsequent erosion to baselevel."[5]

There has been much discussion among geologists as to whether these ridges of trap were formed simultaneously, or whether they are the result of successive outflows, at long intervals of time; and if they were not formed at one period, then which appeared first.[6] Then there is another

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1 The heights here given are taken from the Topographical Atlas of New Jersey.

2 It is thought that the trap mountains of the Ramapo valley are a continuation of the First Watchung sheet.—*The Relations of the Traps of the Newark System in the New Jersey Region*, by Nelson Horatio Darton, Bulletin No. 67, U. S. Geological Survey, Washington, D. C., 1890.

3 As cited above.

4 The curious outlines of the trap ridges are very clearly shown on the Geological Map of New Jersey accompanying the Annual Report of the State Geologist for 1881. The hook at the northerly terminus of the Palisades is in New York State.

5 In a letter to the author. He adds: "There has not been given any good reason for referring the curvature to the attitude of the rocks below, except so far as the uplift of the lower rocks accompanied the uplift of the Triassic formation."

6 In the American Journal of Science, April, 1878, there was published an article by Israel C. Russell, "On the Intrusive Nature of the Triassic Trap Sheets of New Jersey," in which the writer relates how

question of peculiar interest as bearing on the Geological History of the Passaic Falls: Were these trap rocks formed by the intrusive flow of the lava between the layers of sandstone and shale, the upper layers of the softer rocks being subsequently eroded or worn away? Or, did the trap, in at least some places, overflow the sandstone, and become immediately exposed to the air, as at present?

Let us see how the earth's surface in this neighborhood has changed since those early days. As already remarked, the Archæan ranges in Northern New Jersey were washed by the ocean, which dashed in wild waves against their base, ground the rocks into fragments and strewed them in the shallow water along the shore. Wind and rain aided in the erosion and denudation, and gradually the debris at

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he discovered, near Feltville, on the western slope of First Mountain, a spot where the trap rock was overlaid by a bed of sandstone and shale twenty-five or thirty feet thick. He regarded this as "indisputable evidence that the igneous rocks, composing the First Newark Mountain, were intruded in a molten state between the layers of the stratified rocks subsequent to their consolidation." In a paper by the same writer, "On the Geology of Hudson County, New Jersey," read before the New York Academy of Sciences, April, 1880, and published in its "Annals," he gives many additional reasons for this conclusion, and argues that Bergen Hill was at one time covered by sandstone and shale 7,000 to 8,000 feet thick. In 1882 Davis examined the rocks at Feltville more carefully, and discovered no traces of the alteration described by Rogers, Cook and Russell, but on the contrary found that the vesicular, slag-like rock was overlaid by unaltered shales with an intervening trap breccia (angular fragments of trap) at some points. This breccia was alone considered satisfactory proof of the extrusive nature of the sheet, and he stated his opinion that it could only have been formed on the surface of a pre-existent sheet of lava.—*On the Relations of the Triassic Traps and Sandstones of the U. S.*, by W. M. Davis, in Bulletin Lyceum of Comparative Zoology, Harvard College, 1883, Vol. VII., No. 9. In an article, "The Geological History of New York Island and Harbor," in the Popular Science Monthly, October, 1878, Prof. J. S. Newberry, of Columbia College, assumed that the First and Second Mountains were covered with sandstone and shale to a depth of several hundred feet, at least. The late Prof. George H. Cook, State Geologist of New Jersey, 1863-1889, concluded that the trap rocks were "of older age than the red sandstone and shale in which they occur, and that they were intruded after those sedimentary rocks had been elevated to their present position," "although they may have overflowed for short distances, from the out-crop of their intrusive sheet."—*Annual Reports*, 1883, *p.* 22; 1886, *p.* 127.

the base of the mountains spread further and further out into the ocean, till a fringe of mud, and, in time, of sandstone, was formed. This went on and on till there was an almost level plain (a peneplain[1]) of sandstone, extending from the Archæan ridges on the west to and beyond the present Hudson river on the east. The territory of New Jersey has never been agitated by lofty volcanoes, belching forth flame and masses of rock; but at certain periods, while the deposition of the red sandstone was going on, great fissures have opened in the crust of the globe, and through them there have welled forth fiery rivers of lava,[2] spreading out over a large part of the surface of the newly-forming rock, before it had become fairly consolidated into stone. These streams continued for an incalculable length of time, and at irregular intervals, perhaps centuries apart. The first of these outflows in this part of New Jersey formed a bed of trap rock hundreds, possibly thousands of feet in thickness,[3] lying in a horizontal position above the sandstone.[4] Then the earth's surface sank slowly below the ocean level, and a new bed of sandstone was deposited, of unknown depth, above the trap rock. New fissures were opened, and fresh streams of lava poured forth, spreading out over the most recent sandstone, and, where this had been worn off, then upon the former beds of lava.[5] It was proba-

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1 This word was coined by Davis.

2 "The igneous rocks of New Jersey are remarkably uniform petrographically, as they are all basalts varying mainly in structure and development. The eruptions are fine grained generally, somewhat glassy, and the intrusives are coarser grained, generally being doleritic, in some cases inclosing considerable biotite and often near gabbro in structure."—*Darton*, as cited.

3 The southern edge of the trap sheet, at Rocky Hill, is estimated to be fifteen hundred or two thousand feet thick. This would indicate an enormous depth originally, at Paterson, and a vast extension of its northern edge skyward. Only a fragment of this edge now remains.

4 There is no evidence of successive lava flows in First Mountain.

5 In 1882 Prof. Davis found the base of the Second Watchung mountain resting on apparent tuff (tufa, volcanic rock) deposits on the west bank of the Passaic river a short distance below Little Falls, indicating that there had been a second overflow of lava. The conformable beds and the amygdular (having almond-shaped crevices) and ropy-surfaced rock

bly at this time that the lava rising through a fissure that did not extend to the surface, forced its way between beds of sandstone, which, being subsequently worn and scraped off, left the bold escarpment of the Palisades. [1]

Neither the sandstone nor the trap was for a moment at rest. Born of the warring elements, both, true to their origin, were forever at strife with themselves and with each other. They were no sooner deposited than they strove to change their position. Then there was a Titanic struggle! The sandstone exerted itself to the very base of its vast depth to gather strength to hurl off the enormous superincumbent mass of lava. The contest lasted for ages, is waging yet! The victory thus far is with neither of the writhing combatants. The under one, it is true, uplifted itself, and at the same time with a gigantic effort heaved up the overlying beds of lava, which were in many places fractured in the struggle, and their rough edges exposed to the denuding influences of air and water. This tilting of the lava or trap rock beds has occurred more than once. The uplift has not been equal throughout the Triassic region; some parts of the trap have been raised higher than others. Nor has the erosion been always and everywhere at the same rate. In the mighty warfare of the rocks, "faults" have occurred in the lava bed at our famed cataract, one part sinking and another rising, and so

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of the First Mountain trap are exposed at Morris Mountain and at Garret Mountain.—*Darton*, as cited. Prof. Cook called attention to the underlying bed of conglomerate at Morris Mountain, in his Report for 1882 (p.36), and made some very suggestive remarks on its significance. What Prof. Cook said was always regarded with great respect by geologists throughout the world.

[1] "The extrusive sheets are characterized by their deep vesicularity and alteration, or slag-like aspect of their upper surfaces, the unaltered and undisturbed condition of the enclosing strata, the presence of trap breccias at their bases, the evidence of successive flows, their relations to anterior tuff deposits, and their distinctive columnar structure and petrography. The intrusive sheets are characterized by irregular lower contacts in which the trap cuts across the ragged edges of the strata for greater or less distances, the intense alteration in the enclosing strata, the increased density and fineness of grain, and the bedded structure in the trap near the contacts, and the absence of vesicularity and breccias." —*Darton*, as cited above.

there have been fractures and fissures, which are ever widening, from the movements of the rocks, and the wear of the elements. The upturned edge of the trap rock has been eroded unevenly, as the texture of the lava itself varied, and other forces, yet to be named, were tirelessly, incessantly at work.

And so it is that to-day, instead of a dull, uninteresting plain, we behold the beautifully-diversified landscape of the Triassic region of Northern New Jersey, of which the trap ridges of the Palisades and the First and Second Mountains, with the lovely intervening valleys, are such conspicuous and delightful features, and amid which the most striking and fascinating spectacle in all its varied natural scenery has been the Passaic Falls.[1]

When was the Passaic river first[2] formed? When did its waters first pour over the present cataract at Paterson? From the time the Archæan ridges lifted their heads above the ocean, the rains descending upon them have formed channels wherein they might the more readily find their way back to the sea. As the Appalachian chain has always sloped toward the southeast, the rivers of the Atlantic coast have uniformly flowed in the same direction, except where diverted by local causes. So this Triassic country was plowed by water courses in that far off age, and they had their share in wearing away the rocks, both sandstone and trap. The location of those streams it would not be easy to determine now, but they would naturally be

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[1] In this account of the origin of the present topography of the Triassic region the writer has adopted the views of Davis and of Darton, the most recent systematic investigators of this section of New Jersey. These views are fully given in a paper on "The Geographical Development of Northern New Jersey," by William Morris Davis and J. Walter Wood, Jr., in Proceedings of the Boston Society of Natural History, Vol. XXIV., November, 1889; "The Rivers of Northern New Jersey," by William Morris Davis, in the National Geographic Magazine, Vol. II., May, 1890, pp. 81–110; "The Relations of the Traps of the Newark System in the New Jersey Region," by Nelson Horatio Darton, in Bulletin No. 67, of the U. S. Geological Survey, Washington, 1890. Particular acknowledgment is due to Prof. Davis, who was kind enough to revise the proofs of this part of this paper, and to suggest some corrections and alterations from his own profound knowlege of this locality.

[2] This expresssion, "*first* formed," is used advisedly.

in the valleys between the trap ridges, and would, as naturally, flow toward the southeast. Take a map of New Jersey, and you will observe that all the rivers in this section have this course. There is a part exception—that portion of the Passaic river which, above the Big Piece meadows, flows northeasterly and northerly, but so reluctantly as to suggest that it has been diverted from its true course, and might be easily persuaded to return to it. Although there is no direct evidence of it, the dip of the Cretaceous formation in Central and Southern New Jersey indicates that it would, if extended, reach the base of Schooley's Mountain, and cover all the trap regions, and Prof. Davis believes that was the case when, at the close of the Triassic period, this locality was submerged in the ocean. This submergence would be gradual, of course; so would be the deposit of pulverized shells, and there is every reason for believing that the rivers could easily hold substantially to their old courses, perhaps rising to higher levels as the chalk deposits accumulated. In some cases the beds of rivers were determined by "faults" in the mountain ridges. The Pequannock is located on an ancient fault line, the beds of the corresponding rocks on the opposite sides of its valley differing a thousand feet. There is some reason for believing that a similar "fault" exists in the Wanaque valley. The Pequannock, Wanaque and Ramapo rivers found their way southeasterly across or through the trap ridges to a point probably north of Paterson, and so formed what is now the lower part of the Passaic river. Another stream flowed through the ridge at Little Falls, on to and through the Great Notch (where traces of water action are still discernible), not unlikely carving out the original channel of the primal Third river. The Rockaway found a more direct way to the ocean by uniting with the Rahway, and the more remote headwaters of the Passaic joined their nearest neighbor, the Raritan. All these streams were then, as now, forever seeking the lowest channels, and were incessantly fretting away their banks. As they widened and deepened they "captured" the nearest tributaries. The original Passaic was a larger, fiercer stream than others. It sought and discovered lower depths for its channel. It reached out and found other streams to add to its volume. Its appetite was whetted by what it fed on. After a while the river flowing through Little Falls and the Great Notch became its prey. Still unsatisfied it extended its grasp, and in time seized upon the Rockaway, diverting it from its Rahway outlet. This history was repeated, till the upper part of the river, gorged to repletion, had barely current enough, or was too unwilling, to turn from its obviously natural course, and flow northward to the sea by way of Paterson.[1] This predatory disposition of the ancient Passaic has led Prof. Davis to term it a "piratical" river. But however apt the phrase to characterize its youth, our lovely, tranquil stream has atoned for its early indiscretions by thousands of years of most decorous behavior.

It has been suggested above that the headwaters of the Passaic joined the main river somewhere north of the present Paterson. The sudden ending of the First Mountain at Garret Rock and at the Falls, to emerge again near Sicomac, suggests a "fault," or a subsidence in the lava bed, or else a softer texture of the rock that formerly filled this gap. The tilting up of the bed of lava here, and the exposure of its fractured edge,[2] have aided in wearing it away more rapidly than otherwise would have been the case. The river gladly leaped over this edge, as the shortest way to the ocean, and added its power to the atmospheric forces to back the cataract up stream, ever grinding and eating away the less hard portions of the rock, until at last the water was half imprisoned in the narrow chasm where we now see it struggling desperately to escape, and compelled to turn sharply upon itself ere it regains its liberty.

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1 See Davis and Wood, as cited, on "The Geographical Development of Northern New Jersey," and Davis on "The Rivers of Northern New Jersey."

2 "A geological examination of the district leads to the conviction that the trap sheets, like the sedimentary beds between them, have formerly had a great extension upward along the plane of their dip, into the air, just as they still have an undetermined extension downward into the ground; their present edges simply mark the lines back to which the sheets have been consumed by denuding forces of one kind or another."—*Davis and Wood*, as above.

With the dawn of the Quaternary age there came another prodigious change over the northern part of the American continent. The surface of the globe was slowly elevated—moderately in this latitude, and several hundred feet as far north as Labrador.[1] For some reason as yet not understood[2] the earth in the higher latitudes, where a temperate climate had previously prevailed, was now subjected to a great precipitation of moisture, turning first into snow and then into ice ; this increased the condensation of moisture, and the ice went on forming, thickening and spreading out, from the Atlantic ocean to the Rocky Mountains, and from the Arctic regions as far south as Perth Amboy in New Jersey, its boundary in this State being generally a line drawn from Perth Amboy northwesterly to Rockaway and thence slightly southwesterly to the Delaware river near Oxford. [3] Its southern border extended westward in an irregular line, the Ohio and Missouri rivers roughly marking its lower terminus in the Mississippi valley. Thus this great ice sheet covered an area of four million square miles in America. An area of half the size in Europe was buried at the same time under an icy covering. The slope of the

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[1] Warren Upham estimates the pre-glacial uplift in the vicinity of New York and Philadelphia at 1,200 feet above its present level. The famous Saguenay river below Quebec has a depth of from 300 to 840 feet below sea level; its channel must have been eroded when the land in its neighborhood was 1,000 feet higher than now.—*The Ice Age in North America*, by G. Frederick Wright, New York, 1891, pp. 577–8; *Proceedings of the Boston Society of Natural History*, XXIV., 453.

[2] It seems to be generally admitted now by geologists that elevation of the land is not enough alone to produce glaciation; constant moisture, causing snow deposits, is more important. Nor is intense cold necessary, for some of the Alaskan and most of the Alpine glaciers descend to within 3,000 or 4,000 feet of the ocean's level. The various theories and the objections to them are clearly presented in Dr. Wright's "Ice Age in America," pp. 405–447, and in his "Man and the Glacial Period," 1892, pp. 302–331. In an appendix to the former work (pp. 573–595) Warren Upham exhaustively reviews the whole subject, and presents a very plausible hypothesis of his own. His copious references are a valuable contribution to the bibliography of the subject. See also article by Prof. J. S. Newberry in the Popular Science Monthly, November, 1886, on "North America in the Ice Age."

[3] Its terminal moraine (the debris deposited at its margin) is very clearly shown on the Geological Map of New Jersey, 1886.

frigid blanket in America was not uniform, but it was sufficient to give the whole mass a southern impetus.[1] Near Summit and Feltville, in New Jersey, about a mile from its edge, the thickness was probably a thousand feet. In the neighborhood of the Catskills the slope was only about seventeen feet to the mile, and further north the surface of the ice sheet approximated to a great level plain.[2] The average ascent in this part of the country was probably twenty-five feet per mile, for the first one hundred or two hundred miles,[3] and the average thickness of the glacier throughout its entire extent was at least three quarters of a mile,[4] while in some sections it may have been two miles or more. "The ice-current passed over the Green Mountains where they are from 3,000 to 5,000 feet in height in a course diagonal to that of their general direction, showing that such a mountain-chain made scarcely more of a ripple in the moving mass than a sunken log would make in a shallow river."[5] At the Delaware Water Gap, the valley was filled with a frozen river eighteen hundred feet deep, rising six hundred feet above the Kittatinny Mountains.[6]

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[1] The glacier moved into New Jersey from the northeast. Maps showing the general movements of the great ice sheet are given in the Sixth Annual Report U. S. Geological Survey, p. 205, and in Wright's Ice Age in North America, p. 175. The direction of movement was not uniform, but varied according to local and other conditions. At the gap west of High Mountain, near Paterson, the glacial scratches on the trap rock are S. 30° to 40° W.; at Second Mountain, west of Paterson, the direction is S. 80° W.; on the Little Falls road, S. 75° W.; at Paramus, near the Reformed church, S. 30° W. Particularly near the southern border of the ice sheet it would branch off in various directions, instead of having a single movement.—*Annual Report State Geologist*, 1878, p. 10. It has been estimated that "the rate of motion of the glacier could hardly have exceeded a foot a day, and may have been in most parts no more than a foot a week."—*Dana*, as cited, 539.

[2] Prof. John C. Smock, now (1892) State Geologist of New Jersey, in American Journal of Science, vol. 125, 1883, p. 339.

[3] Warren Upham, in Proceedings Boston Society of Natural History, XXIV., 451.

[4] Wright, Man and the Glacial Period, 330.

[5] Wright, The Ice Age in North America, 166.

[6] Second Gelogical Survey of Pennsylvannia, Vol. Z, p. XIV. An admirable little sketch, "On the Glacial and Modified Drift" of New Jersey, is given in the State Geologist's Report for 1878, pp. 8–23, being

This point was only about ten miles from the margin of the ice sheet, while Paterson is twenty miles north of the ancient terminal moraine. It is safe to assume that the glacier was quite two thousand feet thick over the present bed of the Passaic river, and rose fully fifteen hundred feet above Garret Rock as we now see it.

The mighty power of this enormous mass, with a pressure of scores of tons[1] to the square foot, can hardly be imagined. The vast forests that covered the earth were torn up by the roots and carried along by the resistless force of the Glacier, ground to bits, or deposited as mutilated logs in the depressions passed over. Loose soil and soft rock was relentlessly scraped off and carried along to be deposited here and there in wide depressions, or to be piled up on the mountain sides, two, three or five thousand feet above the level of the sea. Fragments of projecting cliffs were broken off, weighing thousands of tons, at times as big as good-sized houses, and then were dropped upon lofty plateaus to be the wonder of men to-day.[2] Other rocks were ground together and finally left be-

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the first detailed account published of the glacial action in New Jersey, although it had been referred to in the Report for 1877. The subject is treated at greater length in the Annual Report for 1880, pp. 14–97. In the Report for 1891 (pp. 35–108), Prof. R. D. Salisbury, of the U. S. Geological Survey, writes very fully " On Drift or Pleistocene Formations of New Jersey," the paper being well illustrated.

[1] Dana estimates the weight of the ice at 450 pounds per square inch for every 1,000 feet of thickness.—*Manual of Geology*, 539. This would be 48 tons per square foot where the thickness was 1,500 feet, as it is estimated to have been on Garret Mountain, and 64 tons per square foot in the lower Passaic valley. Prof. Newberry, in the Popular Science Monthly, November, 1886, estimates the pressure of ice 1,000 feet thick, at 54,810 pounds to the square foot.

[2] Mount Washington presents many examples. Near Paterson, on High Mountain, 878 feet above tide water, the ledges show the southward movement of the ice, and there are many boulders from three to ten feet in diameter perched on the smooth ledges. Many in New England are described and illustrated in Wright's " Ice Age in North America," pp. 205 et seq. One weighs 2,300 tons; another, at Fall River, 5,400 tons; Mohegan Rock, Montville, Conn., 10,000 tons. Near Drakestown, Morris county, N. J., a mass of blue limestone, 36x30 feet, was quarried for years, to a depth of 20 feet, before it was discov-

hind as huge boulders. Even the hard trap rock about Paterson was scraped and ground away to an extent impossible to estimate[1] by this enormous Glacier, aided by the action of the frost and water flowing beneath the accumulating mass of ice.

We owe to glacial action much of the beauty of the landscape in various parts of the country. It is believed that in pre-glacial times there were few waterfalls and fewer lakes, as to-day they are seldom found beyond the regions of glacial drift. The moving ice sheet occasionally mowed down the divide between watersheds, and on the other hand frequently choked up ancient watercourses. In this way it furthered the schemes of predatory rivers. It would seem probable that thus the united Pequannock-Wanaque-Ramapo river, which previously formed the headwaters of the Passaic, was diverted into the Pompton, and so went to swell the Third river, which then extended through the Great Notch and beyond Little Falls. But the same action which thus diverted these important tributaries from their old channel, in the course of ages choked up the gap at the Great Notch, and co-operated in the efforts of the Passaic to capture the headwaters of the Third river, and at the same time restored to its rightful owner the streams which for a while had fallen prey to its rival. The beautifully-rounded hills of earth, often gathered together like sheep huddling in a field;[2] the broad plains of alluvial soil, the lovely lakes that gem so many of our mountain tops, the valleys filled with fertility, the long slopes adorned with richest verdure, and not infrequently the dancing brooks that leap down the hillsides and meander through green

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ered to be a boulder, transported by glacial action from the limestone range to the northwest.—*Annual Report State Geologist*, 1880, *p.* 30. Boulders of gneiss twenty feet long are found in the drift near Oldham brook, west of Paterson. They must have been carried ten or fifteen miles at least.

1 "Along this whole Appalachian border there were formerly Archæan highlands of indefinite height of which the stumps are all that now remain in the present hills and mountains."—*Wright*, *The Ice Age in North America*, *p.* 438. Their reduction in size is due to pre-glacial denudation even more than to glacial erosion.

2 And hence called *roches moutonnees*.

meadows—all are due to that vast ice sheet that once covered the earth like a winding sheet. So often is death the gateway to life and loveliness. South of Paterson the soil is in many places underlaid with a deep bed of small rounded boulders and pebbles, overlaid by a bed of clay. These are also the result of glacial action. The long train of boulders lying on the ground east of the Erie railway, between Clay street and Lake View, have been brought scores, perhaps hundreds of miles, and deposited there by the glacier of prehistoric days. There are few or no signs of any important alteration having been wrought at the Passaic Falls by glacial action, although undoubtedly frost has done much to wear away the edge of the lava sheet. But unlike Niagara, Minnehaha and most other cataracts, our own Falls do not owe their origin to the damming up of a previous channel by glacial drift. The only ancient water-course possible between the First and Second Mountains was over the bed of trap. The river has formerly flowed at a much higher elevation than now, and may have poured over the lava edge at any one of a dozen places between Garret Rock and the ridge west of Totowa, but it has always kept within those limits. It is very probable that during the Glacial age the river below the Falls was choked up with debris, which was washed out at the close of that period. It is also likely that when the last ice had disappeared, the river was plunging over the long stretch of precipice, extending from the northerly extremity of the chasm through which it now pours, to the southerly extremity of the chasm or ravine adjoining the Little Falls road south of Spruce street. The water constantly wearing down the channel has found its present bed, wherein it has flowed certainly for two centuries; and perhaps for ten thousand years.[1]

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[1] The Niagara Falls have receded seven miles through the hard limestone in which the river has cut its channel. The most careful, accurate observations and measurements have led geologists to agree within the past few years that this recession has taken place since the glacial period, and probably within seven thousand years.—*Wright*, Ice Age in North America, 458.

As just remarked, the Glacial age[1] was remarkable for the formation of lakes, sometimes by the erosion of valleys, making extensive basins, and in many cases by the deposition of debris, decomposed by the Glacier, which raised dams across the ancient beds of rivers, and so held the water back. Such a dam was piled up at the present Passaic Falls, extending from Totowa across the valley to Garret Rock. Through thousands of years it increased in volume, until the water rose to a height of three hundred and eighty feet above the sea, or more than two hundred feet higher than the bed of the river as it is now above the Falls. Thus a lake was formed, more than thirty miles long, two hundred feet or more in depth, and from one to seven miles in width. The ancient shingled beaches of this prehistoric "Lake Passaic," as it has been happily named, may still be traced[2] by the careful observer at Totowa, in the sand hills above Browertown, on the Preakness mountains, at Bloom-

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[1] It should be noted here that of late years geologists have generally agreed that there have been at least two Glacial periods in America. Mr. W. J. McGee, of the U. S. Geological Survey, in an address before the Geological Society of America, August, 1892, expressed the belief that there had been three successive ice sheets, separated by warm epochs; the first ice age, he thought, " witnessed a reduction in the area of the land through oceanic submergence; the other ice ages showed less submergence, but in none of them was the elevation much greater than is now presented along the coast." In 1891 Prof. Rollin D. Salisbury, of the U. S. Geological Survey, discovered what he considered unmistakable evidences in New Jersey of drift deposited by an earlier Glacier than the one whose terminal moraine ends about the latitude of Amboy.—*Annual Report State Geologist*, 1891, *pp.* 102-8. A map showing the course of the ice sheet (the latest) east of the Missouri river is given in the Sixth Annual Report of the U. S. Geological Survey, 1884-85, p. 205. The results wrought by ice and floods, as described above in the text, may have been effected at one period or another, or by successive eras of glaciers and subsequent floods. It may be added that Dr. Wright doubts a succession of Glacial epochs, although willing to believe that there may have been occasional recessions of the front, lasting a few centuries.—*The Ice Age in North America*, 480 ; *Man and the Glacial Period*, 117.

[2] "In a region where forests afford no obstruction, the observer has merely to bring his eye into the plane once occupied by the water surface, and all the horizontal elements of shore topography are projected in a single line. This line is exhibited to him not merely by the distinctions of light and shade, but by distinctions of color due to the fact

ingdale, at Pompton, on the hills enclosing the lovely Wanaque valley as far north as Ringwood and Hewitt, through the Ramapo valley, and southerly to Liberty Corner, in Somerset county, including all of Pompton Plains, and the country about Chatham and Morristown. It was ten times the size of Lake Hopatcong to-day. At this period, the earth in this part of the country was sixty or sixty-five feet lower than it is now,[1] so that the waters from this great lake leaped directly into the ocean, whose waves dashed against the gloomy cliffs at the present Passaic Falls. As the Glacier had pressed onward southerly it had probably followed the course of the Passaic river, and so deposited along its banks vast quantities of valley drift—small boulders, coarse gravel, fine sand and clay, which were piled up in terraces, rising higher and higher.

Toward the close of the Glacial period, and with the incoming of the Champlain epoch, there was a depression of the earth's surface,[2] accompanied by a great thaw. As the melting of the ice increased, vast floods followed at irregular intervals. At length the lofty dam was swept away, and the imprisoned waters of the ancient lake rushed down across the trap edge to the country below. Finer sand was added to the summits of the terraces, with occasional layers of gravel, suggestive of periods of raging torrents succeeded by seasons of a long-continued even flow of water. During the Drift epoch fragments of

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that the changes of inclination and of soil at the line influence the distribution of many kinds of vegetation. In this manner it is often possible to obtain from the general view evidence of the existence of a faint shore tracing, which could be satisfactorily determined in no other way. The ensemble of a faintly scored shore mark is usually easier to recognize than any of its details."—*G. K. Gilbert*, "*On the Topographic Features of Lake Shores*," *Fifth Annual Report of the U. S. Geological Survey*, 1883-84, *p.* 122.

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1 As shown by beach marks at Mount Pleasant cemetery at Newark; on the bluff at Navesink Highlands; in the gravel hill where the new Pennsylvania Railroad station at Trenton stands; on the hills west of Shark river, and at other points.

2 Probably 150 feet about Philadelphia, and increasing to the north.—*Wright's Ice Age in North America*, 414.

fossiliferous rocks were carried from long distances and deposited by the Glacier along its margin, or perhaps where it met the ocean.[1] Thus by the combined action of ice and water were formed those singular terraces known as Colt's Hill (bounded by Ward, Main, Grand and Prince streets, and removed in 1890-91) and Sandy Hill (now bounded by Market, East Nineteenth, Clay, Chestnut and Vine streets). These hills had flat summits, one hundred and fifty-two feet above tide level. The Broadway Hill, the hill at East Eighteenth street and Seventh avenue, in Paterson, and the sandy hills at Haledon, are all of the same height—one hundred and fifty-two to one hundred and sixty feet; this similarity in height and material, at least as regards Colt's Hill, Sandy Hill and the hills of sand formation at or near Haledon, and at North Paterson, indicates an origin due to the same time and the same cause.

Strange scenes were enacted about the shores of that pre-historic "Lake Passaic." The mammoth, twice the size of the largest elephant of to-day, and covered with reddish wool and black hair, having tusks twelve feet long, curved upwards, roamed about the neighborhood, and occasionally encountered the still huger hairy mastodon.[2] The Greenland reindeer[3] glided swiftly over open spaces across the ice, with the caribou, the bison and the musk ox.[4] The industrious beaver set the precedent for the mighty barrier at the Falls, by damming up the streams that flowed

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[1] Such fragments of rocks, generally sandstone, sometimes yellow and sometimes red or brown, containing fossils, were found in excavating for the cellars of the buildings on the south-east corner of Broadway and Washington street; in digging for the foundations for the new gas works near Lyon street; in grading the Boulevard between Nineteenth and Twentieth avenues, and at other places in Paterson.

[2] The tusk of a mastodon was found in the Trenton gravel, fourteen feet below the surface, in 1878. The remains of another were found more recently near Corona, Bergen county. Bones of the same huge beast have been found in a depression in a "fossil" glacier in Alaska—a glacier that has been stationary so long that it is covered four feet deep with earth in which forest trees are growing.

[3] Remains of the reindeer have been found near Vincenttown.

[4] Remains of all these animals have been found in the glacial drift in New Jersey.

into the Lake. Birds, five or six feet high, with formidable rows of teeth, coursed through the air, or preyed on the fish that swarmed in the waters, while the turkey placidly waxed fat with never a fear of Thanksgiving Day.

But of all the beasts and birds that were wont to make their home near the shores of this great lake, scarcely a member of their species now exists, and the only evidences that they once roamed the earth or air, are the infrequent fossil remains occasionally brought to light by modern excavations. Of "Lake Passaic" itself, the only vestiges left behind are the beach marks made by its waves on the pebbly shores, and the ponds which still exist in the deeper depressions of the old lake basin, such as Pompton Lake, Crystal Lake,[1] and perhaps Franklin Lake. At the close of this period, as the Glacial Lakes[2] disappeared they generally found their way to the ocean by the old valleys and river channels,[3] and when these great bodies of water had gone the rivers shrank to something like their present size and into nearly their present beds, which, however, are always, in the Northern hemisphere, cutting into their right banks, leaving the latter higher and steeper than their left shores.

After the period of vast floods already described, the earth began to rise once more, and New Jersey, which at this epoch did not extend south of a line drawn from Sandy Hook to Trenton, was slowly enlarged even beyond

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1 Annual Report State Geologist, 1890, p. 60.

2 As evidence that the New Jersey lakes are all of glacial formation it is observed that the lakes of the State are confined to the Highland regions, generally in the "drift;" there are no lakes in the State south of Budd's Lake, Morris county.

3 There is no channel in the Passaic river for a mile or two below the Falls; the river simply occupies a valley filled with glacial drift. The writer distinctly recollects that while bathing in the Passaic river when a boy one day about thirty years ago, near the present Clay street bridge at Newark, the tide being unusually low and the water very clear, he saw a well defined channel in the bed of the river, near the middle, ten or twelve feet wide, with steep banks about two feet high; the channel of the old Mill brook was also distinctly visible, where it ran down the river bed and joined the river channel. These channels must have been worn down at a time when their banks were above water.

her present fair proportions, by the emergence from the sea of the beds of sand, marlyte, clay, shell limestone, compact limestone and green sand marl, which make up the southern counties, and which the jealous ocean is again seeking to reclaim as her own. There have been elevations and depressions of the earth's surface since the time when "Lake Passaic" poured its hundred square miles of water through its ruined glacial dam down into the valley of the Passaic, but there is every reason to believe that the Great Falls are to-day substantially as they were when that immense dam was burst asunder, and that the topography of the country about Paterson—of its hills, its valleys, its sand-hill terraces, its river, its principal water-courses—has undergone no change of note since that startling catastrophe.[1]

It was by all the countless changes that have been briefly hinted at rather than described, that the country was prepared for human habitation. The rocky slopes of the trap rock descending to the river bed above the Falls, the underlying strata of sandstone, gravel and "drift" below the Falls, and the sandy soil covering most of the site of the Paterson of to-day, all tend to assure for a large

[1] As already stated, geologists are substantially agreed that the last Glacial period ended from seven to ten thousand years ago. Through what length of time it continued is as yet largely a matter of conjecture. Some think fully a million years. The most conservative view is that of Prestwick (Geology, II., 533-4), who thinks 25,000 years would cover it. Dr. Wright believes (Man and the Glacial Period, 364) that "one hundred thousand years, or even less, might easily include both the slow coming on of the Glacial period and its rapid close." In an article in the Independent (New York) of November 10, 1892, Dr. Wright describes his discovery, in the Summer of 1892, of an ancient channel through which the waters of Lake Huron and its tributaries flowed via Lake Nipissing, Mattawan river and the Ottowa river into the St. Lawrence. This channel was formed after the Glacial era, and before the continent had subsided sufficiently to send the waters of the Great Lakes southerly to form the present Niagara river. The most moderate estimate allows 7,000 to 7,500 years for the wearing back of the Niagara gorge to the Falls as they now are. Dr. Wright thinks the old channel via Lake Nipissing could have been formed in 2,000 or 2,500 years, and hence still believes that 10,000 years is enough to allow for the lapse of time since the disappearance of the continental ice sheet.

population the best drainage and the purest water-supply —two of the most essential requisites to health.

Nature is never at rest.

The transitions that have so often taken place in the past did not occur suddenly, by "some mighty convulsion of nature," as the favorite phase is. Nor should we conclude that such changes have ceased for all time, and that the surface of the earth is to remain as it is forever. Not so. The globe we live on is still undergoing alterations as vast, and with as far-reaching consequences in store, as any in by-gone epochs. "We live in a universe of change: nothing remains the same from one moment to another, and each recorded moment of time has its separate history."[1] The current transformations are proceeding with a deliberation befitting their magnitude. Geologists may differ as to whether it was seven thousand or seventy thousand years since the last Glacier disappeared, and as to whether the history of the earth dates back twenty-two million or one hundred and fifteen million years. The earth's crust may be rising or falling but a few inches in a year. The Passaic Falls may be wearing away at the rate of only two or three inches in a century. But what are centuries in the history of a universe, or in the eyes of Him in whose sight a thousand years "are but as yesterday when it is past, and as a watch in the night"? As Haeckel well says: "From a strictly philosophical point of view, it makes no difference whether we hypothetically assume for these processes ten millions or ten thousand billions of years. *Before us and behind us lies Eternity.*"[2] As we stand and gaze upon that cataract and the volcanic rocks all about, seamed, and rent, and twisted, all telling of the wonderful power of the Creator, we feel what Bryant has so aptly expressed:

> My heart is awed within me when I think
> Of the great miracle that still goes on,
> In silence, round me—the perpetual work
> Of thy creation, finished, yet renewed
> Forever.
> Oh, there is not lost

[1] So wrote that eminent physicist, Prof. Joseph Henry, Director of the Smithsonian Institution, a month before his death, in 1878.

[2] "History of Creation," New York, 1876, Vol. I., 129.

One of earth's charms: upon her bosom yet,
After the flight of untold centuries,
The freshness of her far beginning lies
And yet shall lie.

Artesian Well at the Passaic Rolling Mill, Paterson.

The following is a tabular account of the specimens found in this well, with the depths at which they were taken, in feet. The boring began in September, 1879, and was continued until November, 1880:

DEPTH.	DESCRIPTION OF MATERIALS.
65 feet....	Red sandstone, fine
110 feet....	Red sandstone, coarse
182 feet....	Red sandstone, and a little shale
400 feet....	Red sandstone, shaly
404 feet....	Shale
430 feet....	Red sandstone, fine grained
540 feet....	Sandy shale, soft
540 feet....	Soft shale
565 feet....	Soft shale
565 feet....	Soft shale
585 feet....	Soft shale
600 feet....	Hard sandstone
605 feet....	Soft shale
609 feet....	Soft shale
613 feet....	Soft shale
1,170 feet....	Selenite, 2 x 1 x 1-16th in.
1,180 feet....	Fine quicksand, reddish
1,180 feet....	Fine quicksand, reddish
1,180 feet....	Pyrites
1,370 feet....	Sandy rock, under quicksand
1,400 feet....	Dark red sandstone
1,400 feet....	Light red sandstone
1,415 feet....	Dark red sandstone
1,415 feet....	Light red sandstone
1,415 feet....	Fragments of red sandstone
1,540 feet....	Red sandstone, and a pebble of kaolin
1,700 feet....	Light red sandstone
1,830 feet....	Light red sandstone
1,830 feet....	Light red sandstone
1,830 feet....	Light red stone
2,000 feet....	Red shale
2,020 feet....	Light red sandstone
2,050 feet....	
2,100 feet....	Shaly sandstone

At this depth the attempt to bore through the red sandstone was abandoned, the water being altogether unfit for ordinary use, and the character and amount of the saline impurities giving little hope of success by going deeper. The fact that the rock salt of England, and of some of the other salt mines in Europe, is found in rocks of the same age as this, raises the question whether it may not also be found here. About the end of December, 1880, the tubing was drawn out of the well and the bore was stopped by a seed-bag below 900 feet. The water then rose to within seventeen feet of the top. By putting down a pump forty feet into the well it has been made to yield 100 gallons of water a minute for five hours, without lowering the surface materially. This water has been analyzed, and found to be slightly alkaline, agreeable to the taste, and to contain 13.54 grains of mineral matter to the gallon, and this mostly carbonates of lime and magnesia. The analysis showed in a gallon (58,318 grains):

2.15 grains of magnesia.
3.71 grains of lime.
1.15 grains of soda, with very little potash.
1.08 grains of chlorine.
.55 grains of sulphuric acid.
Not weighed, carbonic acid.

The late Prof. Cook, State Geologist, assumed that these constituents are combined and exist in the water as:

4.51 grains of carbonate of magnesia,
5.95 grains of carbonate of lime,
1.78 grains of common salt,
.37 grains of carbonate of soda,
.93 grains of sulphate of lime.
———
13.54

" These constituents," said Prof. Cook, " are not such as to make the water unwholesome for drinking or for household uses, and they will probably deposit in boilers as a sandy or muddy sediment, and the water can be used for supplying steam-boilers without danger or inconvenience." The well was begun with an eight-inch bore, and was cased with a six-inch tube down to 1120 feet, and the bore from that down to 2100 feet was four and one-half inches.[1]

List of Minerals Found in and about Paterson.

Amethyst. (Quartz.) Silica—Little Falls.
Analcite. Hydrous silicate of sodium and aluminum.—Paterson.
Azurite. Hydrous carbonate of copper.—Passaic Falls.
Datolite. Boro-silicate of calcium.—Paterson.
Hematite. Sesquioxide of iron.—Little Falls.
Pectolite. Pseudomorphs of quartz after this mineral occur in the quarries at Paterson.
Prehnite. Silicate of aluminum and calcium.—Paterson, Little Falls and Browertown.
Quartz. Silica.—Little Falls (amethyst).

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[1] Annual Report of State Geologist, 1880, pp. 163-5.

QUARTZ. Pseudomorphs of quartz after pectolite and other zeolites are reported by Joseph H. Hunt, M. D., as occurring in the quarries at Paterson.

STILBITE. Hydrous silicate of aluminum and calcium.—Little Falls and Paterson.[1]

Prof. R. S. Tarr, of the Geological Department of Cornell University, a recognized authority on mineralogy, at the request of the author of this History for a list of the minerals found in and about Paterson, has kindly written as follows:

"The following is, so far as I know, a complete list, but as I am acquainted with the region only in a general way, it may not be entirely correct. The list embraces all that are reported from there, but local collectors, who know every minute locality and are always on the watch, might be able to add some. Those marked * have been found in good cabinet specimens, possibly also the others."

*Amethyst	*Chabazite	Hornblende	*Quartz
*Analcite	Chlorite	*Laumontite	*Prehnite
*Apophyllite	*Datolite	Limonite	*Quartz pseudomorphs, after pectolite, stilbite, datolite and apophyllite.
Augite	Epidote	Magnetite	
*Azurite	Feldspar	*Malachite	
Biotite	Hematite	*Natrolite	
*Calcite	*Heulandite	*Pectolite	*Stilbite

Doubtless many of the list given by Prof. Tarr have been found no nearer Paterson than the trap rock at Bergen Hill. Possibly all of them may reward the diligent collector in the quarry and other rock excavations in and about Paterson.

The author has a distinct recollection of once finding, many years ago, Chalcopyrite (sulphide of copper and iron) under an overhanging mass of trap in the Valley of the Rocks.

Asbestus was found some years ago in digging a well on Totowa.

Lignite (mineral coal—carbon, hydrogen and oxygen) has been found on High Mountain, and probably elsewhere, in small, thin veins half an inch thick.

Quartz (milky crystals) has been found in many of the excavations in the trap rock in and about Paterson.

SOME SURVEYORS' BENCH-MARKS IN AND NEAR PATERSON.[2]

CENTERVILLE....................................Elevation, 179.50 ft.

This bench-mark is on a small cut in a projecting stone, 4.6 feet above the ground, at the west end of the north abutment of the road bridge over the Morris Canal, 1 mile southwest of Centerville. The point is indicated by an arrow-head.

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[1] The foregoing list is from the Geological Survey, New Jersey. Final Report of the State Geologist, 1889, Vol. II., Part I., pp. 3–24 *b*.

[2] From Geological Survey, New Jersey. Final Report of the State Geologist, Vol. I. (1888), pp. 262–3.

HAWTHORNE..Elevation, 42.83 ft.

A cross cut on the outside corner of the east end of the coping of the north abutment of the New York, Lake Erie and Western railroad bridge over the Passaic river.

LITTLE FALLS.....................................Elevation, 194.90 ft.

A cross cut on the northeast corner of the stone sill of the main front door of the Reformed Church.

LITTLE FALLS.....................................Elevation, 174.67 ft.

A cross cut on the stone coping at the end of the iron railing on the west side of the Passaic river, Morris Canal aqueduct.

MOUNTAIN VIEW....................................Elevation, 175.74 ft.

A cross cut on the north corner of the west end of the coping of the circular wall at the north end of the west abutment of the aqueduct by which the Morris Canal crosses the Pompton river.

PATERSON...Elevation, 108.51 ft.

A cross cut on the south end of the sill of the Main street entrance of St. Boniface Church, at the southeast corner of Main and Slater streets.

PATERSON...Elevation, 100.37 ft.

This bench-mark is a cross cut on the corner-stone at the northeast corner of the Passaic county court-house.

PATERSON...Elevation, 89.92 ft.

A cross cut on the east end of the sill of the main front door of the Market street M. E. Church.

PATERSON...Elevation, 95.94 ft.

A cross cut on the north end of the sill of the main entrance of the First Presbyterian Church.

PATERSON...Elevation, 175.96 ft.

A cross cut on a projection in the lowest corner-stone at the southeast end of the west abutment of the Delaware, Lackawanna and Western railroad bridge over the Morris Canal, between Little Falls and Paterson.

RICHFIELD..Elevation, 182.56 ft.

A cross cut on the north end of the east abutment of the bridge over the Morris Canal. The point is at the end of the timber on which the bridge rests.

OTHER ELEVATIONS IN AND NEAR PATERSON.[1]

Athenia. Rail at Erie station.................................... 134.0
Bearfort Mountain, highest point in county.......................1490.
Bloomingdale. Pequannock river at................................ 284.
Charlotteburgh. North rail at station............................ 718.5

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[1] From Geology of New Jersey, 1868, pp. 831 et seqq., and Geological Survey, New Jersey, Final Report of the State Geologist (1888), Vol. I., p. 290. Barometric measurements are indicated by a *. These are taken from the former work. Mr. John T. Hilton, when City Surveyor of Paterson, ran some levels which indicated that the barometric height of Garret Rock, given here as 534 feet, was somewhere about 200 feet in excess of the actual height. The heights as given are compared with mean tide.

Clifton. Rail at Erie station	66.3
Cooper. Extreme west end of stone dam, outlet of lake	624.0
Echo Lake. Top of boulder, 4 feet from corner fence of Brown's Hotel	985.8
Great Notch, bench on rock, west end of Notch	315.8
Great Notch, centre of road, back of the forks	303.7
Greenwood lake	618.
High Mountain, north of Paterson	879.
Hohokus. Erie track at station	197.5
Little Falls. Passaic river, above dam	158.
Little Falls. Passaic river, below Falls	118.
Macopin lake	890.
Morris Canal—Plane 11, near Bloomfield	176.5
" " —Lock 13, near Pompton	184.5
(The "seventeen-mile level" is between these two points.)	
Newfoundland. South rail at railroad crossing east of station	774.7
Passaic. Rail at main railroad station, N. Y. L. E. & W. R. R.	57.4
Passaic and Essex county line, post on Fairfield road near Singack.	190.3
Paterson. Erie track at Market street	76.8
*Paterson—Morris Canal	174.0
* " —Garret Mountain—top of sandstone in quarry	406.2
* " — " " —top of mountain above quarry	506.4
* " — " " —second crest	523.5
* " —Garret Rock	534.4
Pompton. Sill of Reformed Church	208.0
Pompton lake	202.
Peckman river, at Stanley's mill pond	191.6
Singac. Rail at crossing near station	169.6
Smith's Mills. South rail at crossing	440.2
*Wesel Mountain (U. S. Coast Survey Station, at Great Notch)	583.

Analyses of Trap Rock.[1]

	High M't'n.	Bergen tunnel	Rocky Hill
Silica	51.8	52.6	52.1
Protoxide of iron	12.9	7.8	12.7
Alumina	15.7	17.1	16.7
Magnesia	5.5	10.1	3.2
Lime	9.8	7.8	10.8
Soda	1.4	1.3	2.3
Potash	0.3	0.9	0.8
Water	2.8	1.9	1.4
	100.2	99.5	100.0
Specific gravity	2.94	2.94	2.94

The High Mountain rock analyzed is described as "a peculiar specimen from the summit of the mountain, having the appearance of a garnetiferous syenite."

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[1] From Geology of New Jersey, 1868, pp. 215-17.

The Bergen Hill specimen was "a grey rock, with a bluish tinge of color, and forms the greater portion of the hill. The rock is hard, durable, of a very uniform grain, and is readily broken into blocks. The blocks of the Russ pavement are of this rock. It is composed of hornblende and feldspar."

The Rocky Hill specimen analyzed was "very hard and tough; dark yellowish grey in color; crystalline in structure; weathers to a light grey color."

It will be observed that these specimens vary but little in composition, although the High Mountain trap is extrusive, while the Bergen Hill and the Rocky Hill traps are intrusive. The average of a number of analyses would show more accurately the differences between the rocks. But, as stated before, the greatest difference is in the structure of the two classes of trap.

Native iron exists in trap rock, but only to a fraction of one per cent., so far as the specimens have been examined, and the particles are smaller than a pin's head.—See State Geologist's Reports for 1874, pp. 56–7; 1883, pp. 162–3. The attraction has been so strong on the west side of Garret Mountain, near the Notch, as to induce a considerable waste of time and labor in sinking "iron mines."