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[ F O U R T H S E R I E S . ]

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ART. I.—*The Submarine Great Canyon of the Hudson River*;  
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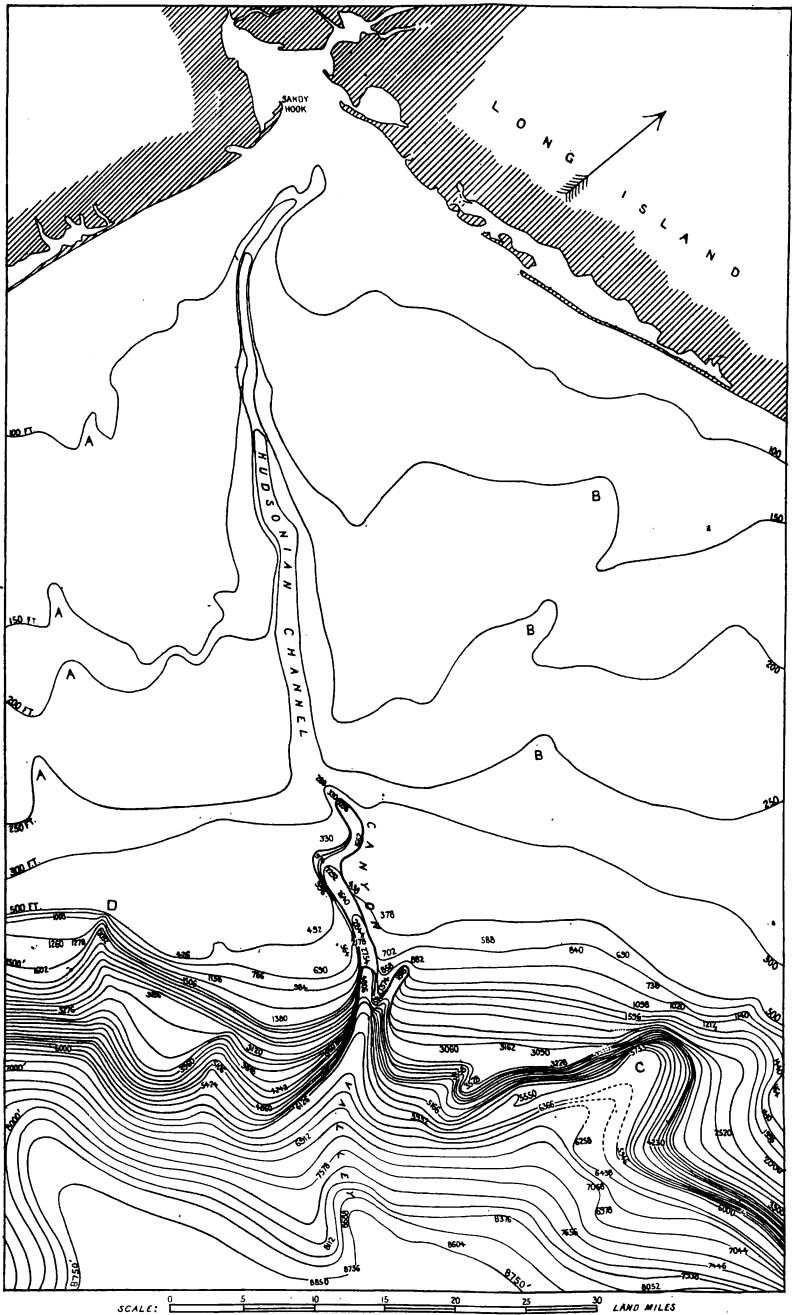
*An Account of what has been done before this date.*

The early work of the Coast Survey brought to light a depression extending from near New York to the border of the Continental shelf. Prof. J. D. Dana was the first to recognize this feature as the submerged channel of the Hudson River, formed when the continent stood at a greater altitude above the sea than it does now. So much importance did he attach to it, as evidence of terrestrial oscillations, that a map of it appeared in all the editions of his *Manual of Geology*, since 1863, but only in the latest edition (1895) was it shown to reach to a greater depth than 720 feet. In the last revision the upper channel and the canyon sections are distinguished, the latter to a depth of over 2000 feet. But the discovery of the canyon was first announced by Prof. A. Lindenkohl in 1885† and further discussed in 1891.‡ He found that it reached to a depth of 2844 feet where the adjacent continental shelf was submerged to only 420 feet—a gorge of 2400 feet in

\* This paper will simultaneously appear in the *Geographical Journal* of London.

† This *Journal* (3), vol. xxix, pp. 475-480, 1885.

‡ *Ib.*, vol. xli, pp. 489-499, 1891.



Map of the Submarine Great Canyon of the Hudson River (by J. W. Spencer).

Soundings in feet. Isobathic lines 250 feet apart, from that of 500 feet to 8,750 feet. Very numerous soundings on continental shelf to 500 feet where the isobaths are 50 feet apart. A A A A and B B B B show course of streams during a late Pleistocene elevation of 250 feet. C is position of the Connecticut canyon or valley, west of which are blank spaces in which the corrected soundings should be 1,896 and 2,340 feet.

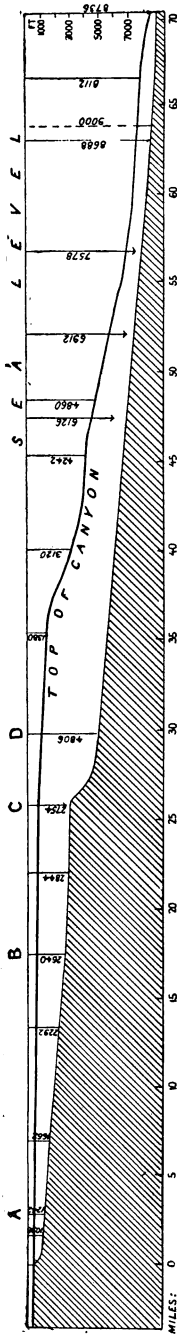


FIGURE 1.—Longitudinal section of Submarine Great Canyon of the Hudson River. At points where depths end in arrows the soundings were not taken in center but on side of the valley. A, E, B, C, D, location of cross sections. E is situated 4 miles above B. Soundings given in feet. Since going to press, from additional information, abrupt steps of 400 and 500 feet respectively are found to occur in the gradient just above depths of 1663 and 2392-foot soundings.

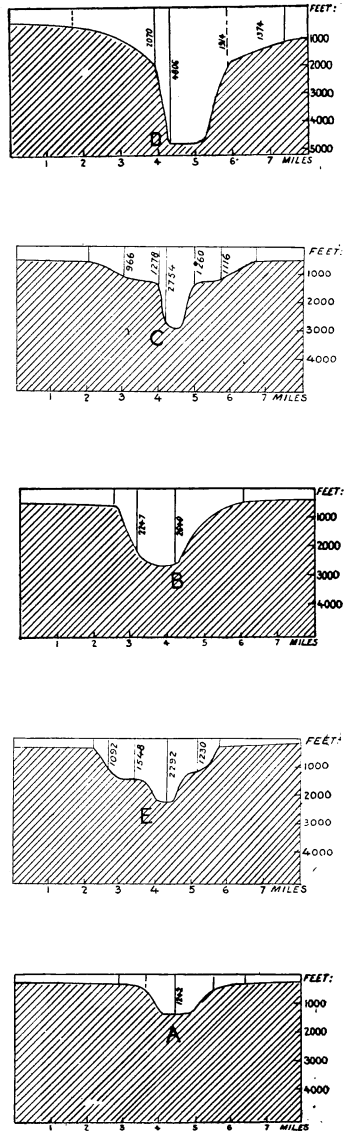


FIGURE 2.—Cross sections located at A, E, B, C, D, in longitudinal sections. Their position on map corresponds to similar depths, in feet, there shown. E (at a point 4 miles above B) and C show the double character of the canyon.

depth. From the soundings beyond the deep point, he at first thought a bar of 1600 feet in height crossed the mouth of the canyon.

In 1889, I pointed out that this canyon, along with those at the mouth of the Gulf of St. Lawrence and of the Maine, could be taken as yardsticks in measuring the late continental elevation to the extent of 3000–3600 feet. This was in the second paper published by the Geological Society of America, the first being by Prof. Dana.\*

A few months later Dr. Warren Upham cited the Hudson canyon among the evidence he brought together to show that elevation was the cause of the glacial period.† In it he attributed the apparent bar to the action of coastwise wave-wash during the subsidence of the continent after the formation of the gorge. Though this bar was a large order for wave action, it was the only reasonable explanation of the deep hole if such it were, as suggested by the Coast Survey chart.

Again in 1890, Prof. Dana published a paper,‡ in which he says that the channel “affords strong evidence of the river origin and therefore the whole channel up to New York was once the course of the Hudson.” In the last edition of his *Manual* he further says (page 948) that the former emergence of the continental border now sunken is proved by the Hudson submerged valley, citing also the cases of the canyons of the gulfs of St. Lawrence and Maine, mentioned above, as evidence of the elevation of the region in the glacial period to at least 3000 feet. It may be here stated that Prof. Dana, on seeing my account of the submarine valleys of the West Indian region, wrote to Prof. Lindenkohl, who replied that he was not aware of them, and hence the note in his *Manual* concerning them (page 949). Prof. Lindenkohl, however, later accepted my interpretation of the much deeper valleys§ which Dana doubted, confirmed by Prof. Lindenkohl’s want of knowledge at the time, though Prof. Dana accepted my St. Lawrence canyon to 3600 feet below sea level.

In 1897 I read a paper before the British Association, stating that with the very insufficient soundings, the Hudsonian valley was recognizable to a depth of 12,000 feet,|| illustrating how we may anticipate where canyons may be found. This paper, amplified into “The Submarine Valleys off the

\* “The High Continental Elevation preceding the Pleistocene Period,” *Bull. Geol. Soc. Am.*, vol. i, pp. 65–70, 1890.

† *Bull. Geol. Soc. Am.*, vol. i, p. 563. Also *Geol. Mag. Lond.* (3), vol. vii, p. 494, 1890.

‡ “Long Island Sound in the Quaternary era, with Observations on the Submarine Hudson River Channel,” *this Journal* (3), vol. xl, p. 425, 1890.

§ *Bull. Geol. Soc. Am.*, vol. xiv, p. 226, 1903.

|| *Ib.*, pp. 207–226.

American Coast," in 1902,\* taking such phenomena as a whole, showed there was accumulative evidence suggesting that these submarine features were gauges for measuring the late great continental elevation.

The most recent discussion including that of the Hudsonian channel (1904) is in Dr. F. Nansen's epoch-making monograph on continental shelves and previous oscillations of shore lines,† reserved for later consideration.

#### *The Hudsonian Canyon.*

The channel described by Lindenkohl begins about ten miles off Sandy Hook and extends for 93 miles before it plunges into the canyon. Land miles and not sea miles will be used throughout this paper. At its head, opposite Sandy Hook, the channel is buried by the sand of the coastwise drift-forming bars, though nearer New York it is much deeper. Lindenkohl had described the depth of the canyon to 2844 feet below sea level, with a bar in front, and no further information is shown on the U. S. Coast Survey charts. In revising my last mentioned paper, I found much additional data on the charts issued by the Hydrographic Office, greatly strengthening the evidence of the continuation of the Hudsonian valley, extending down the continental slope to great depths. But on the British charts I made a most astounding find of three soundings of 459, 801 and 229 fathoms: The position of the 459 and of the 801 soundings of the British chart so closely coincided with those of the Coast Survey chart‡ at 213 and 345 fathom points that they could not have been represented on the same charts. Thus the British chart showed no barrier to the canyon and very greatly increased the known depth of the narrow gorge, further defined by the 229 fathom point. The extraordinary depth would have been startling had it not been anticipated in all of my long series of analyses of submarine valleys. Both series of soundings were correct, the deeper ones having been made by Lt. Com. Z. L. Tanner§ in 1883 in the Fish Commission steamer Albatross. The older soundings had been retained on the Coast Survey charts.

The canyon of the Hudson River may now be extended and revised as follows: The mean edge of the continental border may be taken at a depth of 450–500 feet below sea level. The head of the canyon, in a direct line backward of the edge of

\* *Ib.*

† "The Bathymetrical Features of the North Polar Seas, with a Discussion of the Continental Shelves and Previous Oscillations of Shore Lines," by Fridtjof Nansen. Quarto, pp. 1–232, plates 28. Published in English by the Fridtjof Nansen Fund for the Advancement of Science, Christiania, 1904.

‡ Coast Survey Chart, No. 8. B. A. Chart No. 2480.

§ Hydrographic Notice to Mariners, No. 56, 1883.

the shelf, is 20 miles, but its course is somewhat longer. The upper channel has a depth of 42 feet in the very level sandy plain, which is then submerged to only 288 feet (though a hundred miles from New York harbor). At this point there is an abrupt descent from the bed of the upper part to 1098 feet in the canyon, within the distance of about a mile. The gorge soon deepens to 1242 feet, where cross section A is taken.

The canyon extends nearly due east for six miles, where its depth reaches to 1662 feet. It then bends sharply at right angles to the south, and at 12 miles from its head a narrow inner gorge descends from 1770 to 2292 feet (in a distance of 1.5 miles) where the broad outer canyon attains a depth of only 1500 feet below sea level. Here the shelf is submerged about 250 feet, accordingly the outer and inner canyons have respective depths to 1250 and 2050. A cross section is shown in figure E (added since paper went to press) which is located near the soundings of 2292 feet shown on the map and longitudinal section. Here the canyon turns again at nearly right angles towards the east, though farther on it bends slightly southeastward. A depth of 2640 feet is reached in 18 miles, where cross section B is taken. At 23 miles the depth is 2844 feet, and at 26.5 miles is the position of the 213-fathom sounding, which was supposed to have indicated a bar, and close against which is the discovered sounding of 459 fathoms, as shown in the precipitous wall in cross section C. Nearly midway between these soundings is one of 457 fathoms (the last two not being situated quite in the center of the channel). These, with others on record, but not shown on the published charts, form a chain of soundings from one to two miles apart reaching to near the floor of the inner gorge, thus establishing its continuity. At this locality also, unpublished soundings further show the double canyon, the outer of which, with a breadth of four miles, is revealed to a depth of 1200–1300 feet below sea level, while the inner has a width not exceeding one mile but reaches to over 2800 feet. The gradients and depths of the canyon and their relation to sea level are shown in the longitudinal section figure 1. At 31 miles the 801 fathoms is found, close against that of 345 fathoms not shown on map. This last is on the side of the gorge, of 3800 feet, where the continental slope is further submerged 1000 feet. Here, too, is a great downward pitch in the gradient of 2000 feet in four miles. At this point the maximum breadth of the gorge, nearly 3800 feet above the floor of the canyon, does not exceed two miles, with the bottom necessarily narrower. Seemingly part of the slope of the wall where the deep sounding was found approaches 60 degrees. At 34 miles there is a short tributary from the north, heading in a typical

cove. Beyond this point, where the sounding is more than 4806 feet deep, the canyon feature must continue for several miles at least. I have carried it to the 42-mile point, where the continental shelf is submerged to 3000–3500 feet. At this depth we have several soundings which show that the 3000-foot isobath continues in a direct line as if across the canyon without any known suggestion that it sweeps round into the form of a broadened embayment. Its parallelism to the 500-foot line of the edge of the shelf shows the remarkable regularity of this zone of the great slope. There is also suggested the remains of a shelf or bench of depth corresponding to the Blake plateau south of Cape Hatteras.

Within a few miles the canyon appears to broaden out, and yet at 48 miles there is a steep cliff of 2000 feet or more on its southern side. Here the floor exceeds a submergence of 6126 feet, as the measurement is not in the center of the valley, nor have we obtained the sounding on the opposite northern edge, the last in the gorge being 4800 confined within walls of 3800 feet, though the walls are known on both sides lower down. Indeed this depth is still below that of the continental slope at 48 miles. Evidently the canyon section must reach to a depth of from 6000 to 7000 feet, which also corresponds to the deep valley of the Connecticut. (C on map.)

Beyond the canyon section is the southern side of the extended valley, demonstrated by a line of soundings, though not at its summit. The four soundings at about 8688 feet are specially important as proving the continuation of the Hudsonian valley. The first of these is at 63 miles. At 67 miles the lateral bank is at least 624 feet high (probably 1000 feet at least above the floor), and our record carries the valley to 71 miles from the head of the gorge. The end of this lower reach does not exceed 14 miles in width, but fuller soundings may limit it to 8 or 10 miles. Thus the valley is shown to exist to a depth of 9000 feet.

Beyond this point there are no soundings in the line of the valley, but lateral ones on both sides are suggestive, and at 100 miles east of this study, at a little less than 12,000 feet, is an embayment of 30 miles in breadth, with the depth of a few hundred feet. This cannot be a meaningless feature, though not part of the present analysis.

The breadth of the canyon hardly exceeds a mile at its head, but it soon widens to two miles or more. From the second turn (see map) a breadth of four miles is maintained for the outer canyon. The deeper inner gorge is reduced to a width of one mile or less, and is more sinuous than the outer. Beyond the tributary it is wider, five or six miles, though possibly more, as the next sounding is farther away, but a little

greater or less detail does not alter the general features, and the only important points left relate to the question of the canyon opening out into the valley and its depths, which the analysis shows is 6000–7000 feet, and farther on the characteristics are those of a valley rather than a canyon to 9000 feet below sea level.

*Surface Channels of the Continental shelf and the Deep one of the Connecticut.*

The surface of the continental shelf is a marvellously flat plain, with a mean slope not exceeding three feet per mile. This condition represents a flat substratum, even though there may be hollows in it levelled over by sand deposits. Nearer than Long Island there is no trace of a moraine either buried or submerged. The surface of the plain is covered over with sea-washed sand, except in the Hudsonian channel. This adjective termination I have long used to designate the drowned sections of the river valleys. The sandy plain is traversed by shallow channels shown on each side of the map at AAAA and BBB. These would be still better followed if more isobathic lines were introduced. It is to a depth of 250 feet that these channels are most noticeable. They represent the stream action of an epoch of elevation to this amount since the time of canyon making, and subsequent to the levelling over of the plain after that date. That is to say, these channels absolutely belong to a post-Columbia or Pleistocene epoch,—the canyons to a pre-Columbia or early glacial time. During Columbia oscillations wave action has obliterated all traces of delta form.

The channel of the Hudson river in crossing the submarine plain shows a bottom of blue clay with sandy material in places. But the course of the old upper channel must have been still defined to have allowed its reopening during the epoch of reëlevation of 250 feet just mentioned.

In the canyon section, the bottom is composed of blue clay with fine sand. Beyond it the continental slope is also surfaced with blue clay or green clay, as shown by many soundings.

The great Connecticut canyon or valley, asked for by Lindenkohl,\* is represented (at C on the map) by a deep embayment, whose west wall is at least 3600 feet high, and it reaches to a depth of 5736 feet below the surface of the sea, but the information is not at hand to define its form, though a canyon perhaps passing into a valley at this point might be expected.

At D, on the other side of the map, one sees a cove or amphitheatre such as are commonly indenting the borders of high

\* Bull. Geol. Soc. Am., vol. xiv, p. 226, 1903.

plateaus. I may have too strongly represented the feature on the map, but it is not one of special importance.

*Constitution of the Continental Shelf.*

All our classic teaching tells us that, during the earlier and middle Mesozoic era and far into the Cretaceous period, the continent here was so elevated and subjected to denudation that the sediments were carried far seaward. We cannot go into the question as to their covering the continental slope, but it would seem that the continental shelf now submerged was subjected to the same conditions as those now underlying the coastal plains of the adjacent lands. On these we learn that besides a few hundred feet of Potomac sands, which probably thin out, there are deposits of sand, greensand, clay and clay marl of the upper Cretaceous formations reaching a thickness of 800–1100 feet. Then follow some Eocene sands succeeded by clayey, marly and sandy beds belonging to the Miocene beds. These occur in an artesian well boring at Atlantic City, reaching to a depth of 1400 feet (without penetrating the series or the limited Eocene sands or obtaining water at the lower depths though somewhat higher fresh water occurs, indicating the leaching out of the salt sea water during an epoch of elevation). All below 265 feet is Miocene. This upper part is composed of sand gravel and clay, which may represent important features requiring a word of explanation. Of red gravel sand and stiff clay loam are composed both the Lafayette and Columbia formations, each of which is a thin sheet except where filling valleys. The Lafayette is provisionally regarded as belonging to the end of the Pliocene period, occurring below morainic material as I have seen in New Jersey. But it has been enormously denuded. The Columbia formation (now subject to subdivision) is the material of the Lafayette redeposited, and overlies the drift, with its surface only moderately sculptured. I should suspect that at Atlantic City is a buried channel filled mostly with these deposits of the Columbia period, capped with more recent alluvium. These upper beds are substantially horizontal, with the Miocene dipping a little more. For the details of the Miocene deposits in the Atlantic City well see the paper by Mr. L. Woolman\*.

Thus not knowing whether these incoherent formations have a greater or less aggregate thickness, beneath the submerged coastal plains, there are only known little over 2200 feet to be accounted for from the adjacent shores. But they have formed the subsurface of the level plains now submerged, and channelled by the drowned Hudson river, and finally incised by

\* Acad. Nat. Sc., Phil. 1887. p. 339, and vol. for 1890. pp. 132–147.

the canyon on the continental border. Here then, in its upper portion, the gorge penetrates easily denuded material, though some of the beds are composed of remarkably tough clay. Where the sides of the canyon are so precipitous as was shown at the 459 and 801-fathom isobaths, we may suppose that the lower portions are cut out of the harder older rocks, succeeded by more yielding material farther down the submarine valley.

#### *Origin of the Canyon*

It appears that the previous students of the submarine channel have all had the idea that it was formerly a land valley. Such analysis of the phenomena as has been given must be used in discussing its origin under any other hypothesis. While a few other soundings are desirable for fuller local details, we need not one more for a reasonably full discussion of the principles involved—only enough are wanting to stimulate interest in a revision. Not to speak of similar phenomena farther south and in the West Indies discovered by myself,\* and those since brought to light and systematized in a brilliant manner by Prof. Edward Hull of London, situated on the eastern side of the Atlantic basin,† I shall mention the canyon of the Congo discovered by Stassano, and worked out by Mr. J. Y. Buchanan and described by Mr. Edward Stallibrass, and the canyon off Cape Verde described by Mr. Henry Benest, on account of the completeness of detail of such features, not hitherto obtained, but with which the Hudsonian canyon can now be grouped with the advantage of our knowledge of the surrounding physiographical and geological environments, and with the further interest in that it is situated at the main door of the continent.

If formed by river action, the Hudsonian canyon affords proof of startling physical conditions of the region, at a very late date, and hence the whole interest in its origin, for if now a land feature, it would be one of not such unusual occurrence as to awaken our amazement. Can the views of the earlier writers be challenged? The only other possible causes of its origin seem to be:—(1) submarine glacial erosion, (2) open faults, (3) submarine rivers, and (4) a remnant of a primitive depression. This last would only be suggested by an obstinate objector to its fluvial origin, or one unfamiliar with the analyses of such subjects; for after passing the Paleozoic evolution of the continent, what is now its great slope should be covered with detritus carried into the sea during the long period of denudation of the Mesozoic era, thus obscuring older depressions. Some of the African canyons have been attrib-

\* "Reconstruction of the Antillean Continent" and other papers in Bull. Geol. Soc. Am. and in Quar. Jour. Geol. Soc. London.

† Published by the Victoria Institute, London.

uted to submarine rivers. By this the hypothesis of a great elevation of the continent was avoided. There seems nothing in its favor beyond the occurrence of river valleys at great depth, and some floating debris on the sea. As Prof. N. S. Shaler says, subterranean channels must be formed above the base level of erosion; and the establishment of such must precede that of submarine rivers, which soon lose their effectiveness.

Can the question of canyons be cavalierly disposed of by calling them faults? The level continental shelf is covered with Tertiary sands and clays, such as would not favor an open fault theory. The submarine topography on both sides is identical, suggesting not the slightest disturbance to leave an open fault, nor is such shown on the land adjacent. Joints and faults may locate valleys, but the submarine shelf is only a new plain prolonging the Hudson valley, which in slowly rising would force the water to follow the lowest course. The fault theory is not supported by the Great Valley of the Appalachians, extending for a thousand miles, with a breadth of from 20 to 40 miles. And it is in a region abounding in fault; yet the valleys, as have long since been shown by Professors Lesley and Dana, and others, are those of denudation and which I have confirmed in Georgia. Even the gorge of the Delaware Water Gap, where more than a tyro might be pardoned for suspecting a fault left open, is not such according to Professor Lesley and Mr. Chance the geological surveyor of it. The submarine canyon of the Hudson, which is double, the inner the more sinuous, does not lie in a direct line, but turns twice at right angles within a distance of a dozen miles, and below, it widens into a fan-shaped valley. Nansen has described many submarine valleys in the continental shelf of Norway and about Iceland, and does not find it necessary to call in the existence of faults, and even where my evidence has not been full in treating deep submarine valleys, he thinks there is no other feasible explanation, than that the valleys are sunken land features (page 192). Nor will those who appeal to Sir A. Geikie find much comfort in faults. He says:—"To many geologists the mere existence of a valley is evidence of the presence of a fault," and that "in every case actual proof of a fault should be sought for in the tectonic structure of the ground." "In the vast majority of cases in Britain valleys have no connections with faults." From its forms and its associations I think we can dispense with the idea of a fault-made rift, unaffected by atmospheric action; and furthermore, this is not in the region of apparent great tectonic disturbances, but one of remarkable simplicity since in Cretaceous times.

Finally I know of no other reason for appealing to faults as

the cause of such a submarine feature, except as a last resort from accepting the evidence as is set forth in this paper, unless such a reason can be shown to exist other than by negative or insufficient evidence.

As for submarine glacial erosion, I have shown that there are no features of the shelf suggestive of the occurrence of glacial action, even though such reached to Long Island and New Jersey. Furthermore it could not have possibly extended to the great depths of the canyon and the continuing valley. Of this question Dr. Nansen says in his great monograph:—“The drowned valley of the Hudson River cannot possibly have been re-opened by submarine glacial erosion, it is too long and narrow and deep.” (Op. cit. p. 192.) Its analogues of the tropics are situated beyond glacial action.

Of the drowned valley of the Gulf of St. Lawrence, Prof. N. S. Shaler also writes, but I do not remember whether he considers the then discovered Hudson River canyon.

Returning now to long accepted fluvial origin of the submarine channel, let me call attention to the very close resemblance of the canyon, as shown on the map, to the gorge of the Niagara, also excavated out of level plains, far from mountains, in front of which are great slopes to lower levels. But this portion of the Hudsonian canyon is thirty miles long and reaches to thousands of feet in depth, while that of the Niagara is only seven miles in length and now 440 feet deep. So too the canyon of the Hudson is just like the *barrancas* on the high plateaus of Mexico and Central America, starting in level plains, and then suddenly transforming themselves into rapidly descending canyons, which later widen out into such valleys (as we may see in the east, which have reached more mature forms), whose descent from the plateaus of thousands of feet in height is not by regular gradients, but commonly by a succession of great steps.

#### *The Magnitude and the Time of the Great Elevation.*

While it must have taken the Hudsonian canyon many milleniums to have been formed, yet it presents a youthful feature, in strong contrast with the valleys on the eastern side of the American continent, while its submerged marginal shelf is not deeply indented with its surface scored into a succession of ridges and hollows. Even though many of the underlying rocks may be of a resisting nature, yet the period of canyon-making must have been one of limited duration. This is further suggested when considering the size of the Hudson river, which probably carried down glacial waters and detritus for a portion of the period. Outside the limit of the Hudsonian river, the surface of the now submarine plain was

not deeply scored as with atmospheric agents acting for long ages, as would have appeared beneath the superficial mantle had such obtained. One condition might modify this last argument, namely a subsequent long epoch of wave cutting, with the removal of the prominences, such as Nansen describes in his "coast platform" which does not exist here, but in such a case the Hudsonian gorge should have been filled with debris.

In the region of the Great Lakes from the tilting of beaches, I have worked out great epirogenic movements, and it quite prepares me to expect to find a reduction of the amount of elevation of the continent, represented by the present submergence of the valleys along our continental margin due to bending downward of the continental slope, but this would not reduce by any amount that determined in the canyons and the necessary slope of the land surfaces. So also when we find subaerial features submerged, they at least would need to have been depressed to the depth they are now found at, no matter what the cause of depression.

The canyon section has sunken 6,000–7,000 feet and the valley beyond to 9,000 feet. Did I attempt to guess at the reduction of this amount in the late height of the continent, I should be inclined to pause owing to other features outside the line of this study. But if others wish to reduce the continental elevation by 2,000 feet, by extra bending down of the continental slope, I shall not protest farther than by stating that additional evidence beyond our limit may replace it. Provisionally then we may keep the amount of elevation at 9,000 feet as shown here, leaving others to correct the figures if found to be excessive. On the other hand, I have no idea that the present heights of the mountains were relatively nearly so great as now.

Fragments of the Lafayette formation should extend from New Jersey, and underlie the surface of the continental shelf. The great denudation of the region was after the Lafayette period, as was proved by Prof. W. J. McGee. I have found these beds underlying glacial deposits in New Jersey. They are provisionally regarded as Pliocene, unless they are preglacial Pleistocene, as thought by Upham. On the surface of the overlying till, rests the Pleistocene Columbia red loams, sands and gravels, in samples not distinguishable from those of the Lafayette formation except in the smaller size of the gravel. And it is such materials which are obtained in the Atlantic city well (Woolman). The denudation of the Lafayette has been so extensive that its remains would be more likely outside of a channel, buried as this appears by the Columbia formation, which has levelled over and furnished materials for the surface of the continental shelf before the

re-excavation of the small channels at AAAA and BBB on the map (page 2). These channels as mentioned before, represent a re-elevation of the drowned plain to as much as 250 feet in the later Pleistocene period, since which time the region has been again once or twice depressed, then re-elevated slightly and channelled, and is now sinking at the rate of two feet a century (Prof. Mitchel). All of the changes are remarkable repetitions of those which I have shown to have occurred farther south and in the West Indies. Thus it may be seen that the canyon-making period was in the earlier Pleistocene, and accords with Prof. Dana's views as expressed in the last edition of his Manual, and those of Dr. Upham, only the evidence is in more detail, showing a much greater elevation than was then known.

I have not touched upon an earlier Tertiary valley, as such could apply only to great depths beyond the canyon section.

#### *Summary and Conclusion.*

More than 40 years ago, Prof. J. D. Dana first recognized the submarine extension of the Hudson river in the soundings on the continental shelf. In 1885, Prof. A. Lindenkohl discovered the channel suddenly transformed into a canyon near the continental border, reaching to a depth of 2400 feet below the surface of submerged plain, which is here about 400 feet beneath sea-level. But near the then known mouth there appeared a great bar. In 1897, I pointed out that the channel was traceable to great depths, which is now proved. A sounding was made near the supposed bar, which has proved to be only a measurement taken on the side of a deep canyon with a precipitous wall. Then four miles beyond this point, against another lateral bank, a further sounding reaches to 4800 feet, revealing a canyon 3800 feet in depth, where the continental shelf is not submerged more than 1000 feet. High up on the sides, the gorge here is less than two miles wide, but the incision of the outer canyon into the shelf has a breadth of four miles. At its head, the canyon begins in an amphitheatre, having a descent from 330 feet to 1100 feet in the distance of about a mile. Two more steps of 400 and 500 feet respectively follow. Again between 27 and 31 miles below its head, there is another great step of 2000 feet to the depth of 4800 feet mentioned. And the gradient below is probably by other great steps. This is just beyond the border of the submarine plain and shows the canyon with a depth of 3800 feet. The canyon is double, a second or more sinuous gorge traverses the outer. A little farther on is a tributary heading in a cove. At 42 miles the canyon begins to widen into a valley, which at 48 miles has a precipitous wall of 2000 feet in height. The valley opens

into an embayment or wider valley which also receives that from the Connecticut, now discovered to a depth of about 6000 feet for the first time, but without details to describe its form. In cutting through the continental bench, at 3000–3500 feet beneath sea-level, the floor of the canyon is between 6000 and 7000 feet below the surface of the ocean. The valley is continuous to a point 71 miles from the head of the gorge and where it is recognizable at a depth of about 9000 feet.

The canyon and valley discovered to the great depth shown, incising first the level continental shelf, (in which it turns twice at right angles), and then coursing down the great continental slope, is now taken as a gauge for measuring a late high continental elevation of the region to the extent of 9000 feet. This is following out the lines of Dana, Lindenkohl and other students of the submarine channel, in that they considered it a drowned land valley. I have analyzed every other known possible cause of its origin. So great are the probabilities and so long have these been accepted unquestioned, that very strong proof would be required to modify this view.

The period of the great elevation has been found to coincide with that of the early Pleistocene. Since then there has been a subsidence to somewhat below the present level, followed by a re-elevation of 250 feet as seen in the shallow channels of the shelf. With other minor changes, the region is now sinking at the rate of two feet a century.

This canyon feature at our door corroborates the great changes of level worked out most extensively by Hull of Britain, Nansen of Norway, and myself here and in the West Indies, following methods which the father of geography, Prof. J. P. Lesley, predicted in 1888 “must throw light on the whole subject of elevation and subsidence, as applicable to the entire area of the United States.”