ARTICLE VI.

# WRIGHT'S "ICE AGE IN NORTH AMERICA AND ITS BEARINGS ON THE ANTIQUITY OF MAN."[1]

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IN 1874 Mr. James Geikie, of the Geological Survey of Scotland, published a book entitled, "The Great Ice Age and its Relations to the Antiquity of Man." From long continued observations of his own and from a collation of facts stated by others, he was able to present a well-written sketch of the great winter which formerly prevailed over much of the northern hemisphere. For a quarter of a century earlier the generality of writers had accepted the views of the older geologists, that the coldness of the climate had resulted from the multitudinous icebergs originating in the remote north and floating southerly over a submerged continent. To these Mr. Geikie's book came like a revelation; for he does not even take the pains to refute the iceberg theory, and all the facts are explained upon the assumption of the presence of a thick mantle of glacial ice, covering more than the existing *terra firma* because of a continental elevation. The book had a wide circulation, and would seem to have been an important factor in convincing the public of the truth of the glacier theory, besides awakening an interest in the study of surface geology.

[1] With an Appendix on "The Probable Cause of Glaciation" by Warren Upham, F. G. S. A., Assistant on the Geological Surveys of New Hampshire, Minnesota, and the United States. With many new maps and illustrations. New York: D. Appleton & Co. 1889. (pp. xviii. 622. 6¾x3¾.) $5.00.

It was in this same year that the Rev. G. F. Wright, then settled as pastor over the Free Congregational Church in Andover, Mass., commenced that special study of glacial phenomena which has eventuated in the publication of the book now under review. It was not his first thought of geological subjects, as the writer knows by correspondence with him at least a dozen years earlier. He had been a student of various scientific questions that must be discussed in their relations to theology and biblical interpretation, from the very beginning of his ministry; and these investigations show themselves in the interest taken in "Darwiniana" by the late Professor Asa Gray (whose index was prepared by Mr. Wright); in the "Logic of Christian Evidences," "Studies in Science and Religion," "Divine Authority of the Bible," etc. The appearance of Geikie's book undoubtedly stimulated Mr. Wright in the prosecution of researches in glacial geology, as it certainly did his friend Warren Upham, who contributes to this book the Appendix respecting the Probable Cause of Glaciation.

The first subject taken up by our author was the origin of the curious "Indian ridges" visible from his residence, together with the analogous deposits scattered over the neighborhood in Eastern New England. Next came the study of the boundary of the glaciated area in Pennsylvania, in company with the late Professor H. Carvill Lewis, whose joint report constitutes volume Z, of the Second Geological Survey of that State. The summers of 1882 and 1883 were spent in continuing the investigation of this glacial boundary through Ohio, Kentucky, and Indiana. In 1884 and 1885 he was employed by the United States Geological Survey in tracing this boundary across Illinois and reviewing the field in Ohio and Pennsylvania. The summer of 1886 was spent in Washington Territory and upon the Muir Glacier in Alaska. In 1887 and 1888 there were further studies in Dakota and other districts in the Northwest. Fortunately, an opportunity

was afforded to present the whole history of the ice age in a systematic way before the Lowell Institute in Boston in 1887, and before the Peabody Institute in Baltimore in 1888. The book, however, covers a much wider field than the lectures, and naturally presents all the topics with greater fulness.

Besides these special investigations Dr. Wright has been associated with, and become familiar with the views of, several geologists like Upham, Lewis, Chamberlin, and Abbott, who have made a specialty of the study of the surface deposits. As he says himself, he is "but one of many investigators who have been busily engaged for the past fifteen years (to say nothing of what had been previously accomplished) in collecting facts concerning the Glacial period in this country." No one could prepare a volume like his without abundant reference to the work done by others; or if any geologist should detail his own results to the exclusion of pre-existing material, the outcome would lack symmetry. Unpublished information has appeared with the express permission of its authors, and due credit given wherever required.

Inasmuch as the author commenced his glacial researches as late as 1874, he has not found it necessary to enlarge upon many of the earlier views, regarded formerly as highly important. Nor has he followed the theories of any favorite teacher. He has exhibited the existing state of opinion respecting the ice age, with a pardonable deference to his own private views on special topics. It is not to be expected that investigators with different natural proclivities should always agree in matters of detail; and there is apparent a want of concurrence between Dr. Wright and some other authors in regard to certain important interpretations of facts. Attention will be directed to these particulars later; meanwhile it is only needful to say, that from his general ability, his judicial quality of mind, and knowledge of the subject, Dr. Wright is well qualified to have an opinion of his own,

whenever he has been led to differ from his contemporaries.

The subject has been treated of in a systematic way, which is susceptible of a division into four parts: 1. The definition of a glacier and a description of the fields of ice now in motion upon the Pacific slope of North America, in Alaska, in Greenland, and in a general way elsewhere in the world, as in Europe, Asia, South America, and the Antarctic continent. 2. The area embraced by our Eastern American ice-sheet, and all the phenomena illustrating the different phases of the period. This part occupies half of the book, and the topics considered are those which are fundamental and essential to the science of surface geology. 3. There is a discussion of the causes and the date of the ice age. 4. The facts illustrative of the presence of man are considered; whether he lived in the ice age or not, and what limitations of time may be set to his existence upon the continent. Several of the topics discussed will now be more fully referred to.

Nothing could enable one to study glacial phenomena better than the explanation of the masses of ice which are now lying open to observation upon their native slopes. Hence Dr. Wright was led to visit the famous Muir Glacier in Alaska, and to study it with the modern appliances of engineering and photographic art. A thorough knowledge of its topography, the thickness of the ice, its differential motion, the deposits left behind, and a multitude of other details enable us to understand the corresponding phenomena of the continental ice-sheet. A month's time was spent in studying this glacier. It is located upon an inlet at the head of Glacier Bay, in latitude 58° 50′ and longitude 136° 60′, in the very southern part of Alaska, with mountains over

icebergs into the inlet from a front of three hundred feet. Numerous islands of rock project above the surface of the ice, whose summits bear marks of glaciation. The rate of motion of the ice was determined by triangulation. From a measured base-line angles were taken to prominent ice needles or large stones, and these were observed repeatedly during the month, so as to allow of a computation of the distance travelled. Owing to crevasses and the rapid melting of the ice, it was not practicable to measure the rate of motion by a row of stakes planted upon the surface in line with others upon either bank. The rate found was forty feet per day, seventy in the middle, ten upon either shore, and the eastern portion moving more slowly than the western. The water front of the ice is about one mile wide and bergs are constantly falling off from the glacier, as often as every ten minutes. They separate with a loud noise, much like thunder or the booming of cannon, and the inlet is crowded with floating ice of all sizes. Steamers approach quite near the ice, so as to allow the passengers to experience the novel sight of the "calving" of the bergs. The water here is from five to six hundred feet deep.

Every feature of the glacier is carefully described; as, the moraines, both terminal and medial, glacial furrows and smoothings, the *moulins*, glacier tables (all leaning towards the sun), kettle-holes and kames in the process of formation, deltas from the subglacial streams, upright trunks of trees and masses of vegetable matter covered by glacial deposits, and numerous indications of a former extent of the ice miles down the valley towards the ocean. The careful observation of all of these phenomena in the living glacier must greatly enhance the value of the author's generalizations when applied to the interpretation of the corresponding features of the ancient ice-sheet.

For the satisfactory discussion of the most vital topics of the ice age, it will be important to refer to the history of opinions in respect to this period of glacial

time. There are certainly three eras of progress: 1. From the opening of the century down to about 1860, when belief was almost universal in the submergence of the continent and the action of icebergs. 2. An era of about twenty years, when the iceberg theory was gradually being discarded, and the doctrine of a former extension of glaciers took its place. 3. The present decade since the demonstration of the existence of terminal moraines. The science of surface geology has been completely rewritten since these phenomena have been understood.

All will agree that the late President Edward Hitchcock was a leading exponent of the iceberg theory during the first of these evolutionary periods. He commenced to write when his statements respecting the foundation facts of the science were "received by the ablest geologists of our country with strong scepticism," and he was obliged to bear the obloquy of stating what was believed to be irrational. No one now disbelieves his contention of 1841, that the eastern part of our country had been traversed by a mighty force moving southeasterly, which carried boulders, sand, and gravel for a distance of many miles, and over hills and mountains whenever they happened to be in the way. The earlier glacialists claimed, in opposition to this doctrine, that the higher mountain groups, like the White Mountains of New Hampshire, were centres of dispersion, and that they had never been swept over themselves by a grander movement. It was demonstrated to the satisfaction of even the founder of the glacial theory, that both a general and local ice-movement left their monuments in New England. President Hitchcock also

"Final Report upon the Geology of Massachusetts," 1841; "The Phenomena of Drift, or Glacio-Aqueous Action in North America, between the Tertiary and Alluvial Periods," in the "Transactions of the Association of Geologists and Naturalists," 1847; "Illustrations of Surface Geology," published in the "Smithsonian Contributions to Knowledge," 1857; "Elementary Geology," 1860; and the "Final Report upon the Geology of Vermont," 1862.

The announcement of the glacial theory is usually conceded to Agassiz. Being a resident of Switzerland, he must have listened to nursery tales, and the strange stories told by the credulous to youthful lovers of the marvellous, of the singular transportation of large objects by the glaciers. To silence such wild statements must have been a part of the inducement that led him to spend his summer vacation in 1836 among the glaciers of the Rhone in company with Charpentier. He saw, became convinced, and his zeal outran the enthusiasm of his guide. In 1837 at the age of thirty, he boldly enunciated the glacial theory, much to the dismay of his early friends and advisers, Leopold Von Buch and Baron Humboldt. Dr. Buckland, happening to be in Switzerland in 1838, visited the glaciers in company with Agassiz, and became convinced of the truth of their former extension, and on returning to Great Britain discovered that the phenomena of the drift in that country were susceptible of the same explanation. Murchison, in his address of 1842 before the Geological Society of London, said, that the existence of ancient glaciers in Great Britain is not established to the satisfaction of the majority of British geologists. Twenty years later he wrote to Agassiz: "I was wrong in opposing your grand and original idea. . . . . I am now convinced that glaciers did descend from the mountains to the plains, as they now do in Greenland."

Perhaps it will be well to refer to the episode which marks the transition of the surrender of the iceberg to

the glacier theory in Great Britain, from 1860 to 1866. Professor A. C. Ramsay was the prominent agent of the transfer. He possessed the highest scientific attainments, as shown by his official position as Director of the Geological Survey of England. He had visited the United States in 1857 and studied our drift phenomena, which were explained in accordance with the iceberg theory in a paper before the Geological Society of London, in 1859. Very shortly afterward he published a memoir comparing the old glaciers of Wales with those of Switzerland, and claiming the glacial origin of certain rock-basins which support lakes of water. He also expressed the opinion that the alpine blocks on the Jura Mountains had been transported by icebergs across the great valley of Switzerland. After another visit to that country he became satisfied that he should have referred this action to glaciers. Thence it was a brief logical step to the conclusion that similar phenomena in other countries were to be explained in the same way. The following is an epitome of his conclusions:[1] 1. Each of the large Swiss lakes lies in an area once occupied by a glacier. 2. The theory of a special subsidence for each lake basin is unwarrantable. 3. Nor do they lie in lines of gaping fracture. 4. Nor do they occupy synclinal basins. 5. No species of watery erosion can explain the excavation of rocks below a line of motion. 6. But one other agent remains, the glacier, which is a solid body, grinding steadily and powerfully so as to scoop out deep hollows. 7. Hence, if valleys exist, glaciers will excavate lake basins in them. 8. The depth of the lake is proportional mainly to the size of the excavating glacier. Countries that have been glaciated abound in lakes; and on the other hand, lakes are scarce in non-glaciated regions. Ramsay is therefore constrained to return to the theory of Agassiz, that in the period of the extremest cold the northern parts of Europe and of America were covered by sheets of true glacial ice.

[1] Quarterly Journal of the Geological Society (London), Vol. xviii. p. 204.

Of American geologists whose names are associated with the glacial theory, during the period of transition, none are more prominent than those of Professors J. D. Dana and J. S. Newberry. To the first named we owe the enunciation of the true doctrines of the glacial origin of river terraces. In 1849, after describing the terraces of Oregon and California, he compares the higher levels to the lower flats along rivers which are continuous with occasional interruptions due to ledges, from the mouths to the sources. After the deposition of the original flood-plain, let there be an elevation, say fifty feet, and the stream will first wear away a new channel for itself, and then deposit the detritus thus obtained along a new flood-plain at the lower level of fifty feet. A second elevation will enable the stream to erode a new channel and carve out a second set of terraces, giving rise to a third flood-plain, which in its turn may be elevated and channelled out. In later publications it was held that the changes of level were paroxysmal. Still later it was perceived that the changes of level were not essential, since the ice by its rapid melting could supply a sufficiency of water to build up the flood-plains out of which the highest terraces were carved. When the supply of water had been diminished, the lower flood-plains would be deposited. The best development of Professor Dana's views on this subject appears in several memoirs descriptive of the terraces of the Connecticut,[1] of which the more important salient points will be briefly mentioned. The uppermost point where the terraces can be advantageously studied is at the mouth of the Passumpsic River, two hundred and thirty miles from Long Island Sound, and the descent of the river is 460 feet. The highest of the terraces varies somewhat. Below Middletown the descent is very rapid and the study therefore commences at the beginning of the steeper fall. The terraces reach the following altitudes above the river:—

[1] American Journal of Science, 1875–1884.

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|---|---|---|
| Middletown, Conn. | 195 | feet. |
| Hartford, Conn. | 210 | " |
| Springfield, Mass. | 240 | " |
| Northampton, Mass. | about 200 | " |
| North line of Massachusetts. | 206 | " |
| Bellows Falls, Vt. | 207 | " |
| Windsor, Vt. | 206 | " |
| Hanover, N. H. | 207 | " |
| Haverhill, N. H. | 263 | " |
| Mouth of the Passumpsic River. | 225 | " |

The altitude of the river at each of these localities must be added in order to determine the height of the terrace above the sea, which at the northernmost point would be 685 feet. The terraces, therefore, slope towards the sea at essentially the same angle with the stream. But at the time of their formation there is reason to believe that the land was more depressed at the north than at the south; so that the slope of the river must have been less than at present. Applying the estimated figure, the low water of the Connecticut at the mouth of the Passumpsic should be given at 390 feet, or 295 feet lower than it is now.

Were there no depression it would be difficult to understand why the terraces consist of fine sand and clay instead of very coarse gravel. Great pains are taken to estimate the mean annual discharge of the Connecticut River at the time of the maximum flood. The width, depth, and velocity are the data required; and the estimated stream is 2,500 feet wide, 140 feet deep, travelling from three to four miles per hour. This amount of water at any one moment would have been two and a half cubic miles, and the daily discharge about one cubic mile. Hence, the length of time required to remove the entire amount of ice in the valley may have been five years, understanding that the most of it disappeared when the discharge was the greatest. This is a very short period for a geologist to deal with, but ample for the work required.

If the amount of depression increased northerly at the rate mentioned, provided we can start from the present sea-level for our basis, the estuary must have reached as

far as Turner's Falls, and the river higher up would have been a series of still-water stretches with falls at a few distant points. From this we can understand the great abundance of clay at high levels, and the absence of erosion. Dams would not be necessary to explain the origin of the clay. The absence of marine fossils in the region may be due to the brevity of the period of submergence.

These details are given as illustrating the condition of all our northern rivers when the terraces were being formed, according to Professor Dana's views.

Professor Dana has treated of nearly all the topics of surface geology either in his "Manual of Geology," or in articles prepared for the *American Journal of Science*, and the present fashioning of the treatment of the glacial theory shows many traces of his invaluable suggestions. Dr. Newberry's contributions come from one who has traversed every part of the American glacial area, and who early foreshadowed the prevailing doctrines of the origin of the Great Lakes. Both Dana and Newberry have constantly insisted upon a considerable elevation of the continent in the early part of the age.

The advocates of a submersion with attendant icebergs always insisted that if the glacialists would win their case, they must discover extensive terminal moraines. When the writer became convinced of the truth of the glacial theory, after a visit to the glaciers of Switzerland, he began the study of the drift of Long Island, expecting that satisfactory evidence would be found there to verify the surmise that the terminal moraine had an existence. About the end of 1868 he read a paper before the Lyceum of Natural History in New York, and also the Long Island Historical Society, in which he represented the backbone of Long Island to be a part of the terminal moraine of the eastern American ice-sheet. The paper was never published; so that he has never received any credit for this suggestion. Being called to a different field of labor, he did not have the opportunity of following up

the subject; though in giving instruction to his classes he has never failed, from 1868 onward, to advocate this view of the structure of Long Island. Dr. Wright has correctly referred to similar early suggestions by Clarence King for the Elizabeth Islands in Massachusetts, 1876; Mr. Warren Upham for Southeastern Massachusetts and Long Island, 1878; Professor G. H. Cook for New Jersey, 1877; Mr. G. K. Gilbert for the Maumee Valley, in Ohio, 1873; President T. C. Chamberlin for Wisconsin, 1873; Dr. G. M. Dawson for the vicinity of the forty-ninth parallel, 1875. Others who have labored effectively in this field are the late Professor H. C. Lewis, Dr. G. F. Wright, Professors J. E. Todd, R. D. Salisbury, N. S. Shaler, and Mr. W J McGee. The United States Geological Survey and the Geological Survey of Minnesota, through President Chamberlin and Mr. Warren Upham, have done the most effective work in this line.

The discovery of the terminal moraines has given greater prominence to the study of the ice, because, 1. A new interest has been given to the study of surface phenomena. As there is a significance in the position and shapes of moraine hills, those who are familiar with them delight to delineate their outlines and speculate upon the nature of their different appearances. The explorer of a new inhabited region is now sure of finding friends who have observed the peculiarities he is in search of. Professional men are pleased with the opening up of discussions that require exercise, but not fatigue, for their elucidation, and afford recreation from severer studies. 2. The establishment of limits upon one side leads to a discovery of the boundaries upon all sides; to the fixing of the centre of dispersion, to the resolution of glaciated America into several distinct ice-fields, and thus all the phenomena in each area are classified. It is seen that the ice-sheets of British Columbia and of Greenland are independent of the one centering in the Laurentide watershed; that the various movements on the two conti-

nents did not start from the north pole; that if the ice-sheet were continuous from the Atlantic to the Pacific, it is because different fields have met each other. 3. Like other glaciated regions, ours must show a succession of terminal moraines. Hence the history of the age can be written, as every terminal line indicates an epoch. Because of the distinctness of the moraines following the contours of the Great Lakes we have already the doctrine of the existence of two glacial periods separated by a long interval of warmth. The weight of authority seems to authorize this view, although some important features of the facts require fuller discussion; but it is clear that the discovery of these terminal lines has completely revolutionized the study of the science. A treatise discussing the Quaternary period which neglects the mention of these lines and their significance is like the play of Hamlet in which there is no allusion to the Prince of Denmark.

President T. C. Chamberlin and others of the United States Geological Survey advocate the division of the ice age into the early glacial, interglacial, and the later glacial periods, for the following reasons: 1. Trunks of trees and various vegetable peaty accumulations lie between two masses of till. Therefore the ice must have retreated to a great distance, and for a long lapse of time after the deposit of the lower till, so as to allow the growth of the trees and the swampy plants before their burial beneath the readvanced ice-sheet. And the impression prevails that the interglacial period was of much greater duration than either of the ice ages. 2. The extreme terminal edge of the transported blocks is regarded as marking the limit of the ice in the early glacial period, while the lines of interlobate moraines near the Great Lakes indicate the most southern extension of the later ice-sheet. The till of the older deposit is characterized by a wide uniform distribution, rarely ending in a definite ridge. The action of the erosive agents seems to have been feeble and the drain-

age imperfect. The later till exhibits evidence of vigorous glacial action in excavation, accumulation, and drainage. 3. Some claim that the earlier deposits have been the more completely oxidized and decomposed. 4. The unique history of lakes Bonneville and Lahontan in the far west agree with a dual ice age separated by a temperate interval.

Dr. Wright in his book dissents from these conclusions, believing, with the older observers, that the age was but one and undivided. His reasons are: 1. The more complete oxidation of the *débris* along the southern border is naturally accounted for by the fact that this was the first material picked up and transported, and consisted of thoroughly decayed rock. That which was carried later had a fresher look. 2. The uniformity of the more southern till is partly an illusion, since it is largely covered by loess or the finer part of the drift, and thus its true character is obscured. 3. The feebler action in the south may be due to the greater depression of the land farther north. 4. The comparative absence of glacier striæ in the south is due partly to the great depth of loose materials, partly to the less vigorous action of the glacier, while the examples of well-defined glaciation are not wanting. 5. The study of the "forest beds" shows that their existence can be explained by temporary and local recessions of the ice-sheet: and with descriptions of every known case there is a setting forth of the special features illustrative of the limited action. 6. The actual subdivisions of the ice age are clearly seen in the beautiful map of the several terminal moraines in Minnesota by Mr. Upham (page 546). Between Des Moines, Iowa, and the International boundary eleven distinct moraine belts are delineated; and there must be as many more yet to be pointed out, before reaching the central point of divergence. These lines of moraines indicate a gradual disappearance of ice from stage to stage, rather than two periods of maximum glaciation. All these moraines have received special names, and it is

hoped that the great interest of the questions at issue will lead many explorers to trace out their eastern continuation.

To theologians the practical value of these discussions consists in the determination of the length in years of the ice age; and upon this subject the concessions of the geologists are really surprising. The upshot of the Niagara Falls discussions is that the gorge is 7,000 years old, and hence this figure represents the time that has elapsed since the ice melted away from the Lewiston escarpment. Dr. Wright quotes with approbation the opinion of Professor Prestwich that the entire period of extreme cold may not have lasted longer than from 15,000 to 25,000 years. Hence the whole of the Quaternary period may not be longer than the 36,000 years formerly supposed to represent the age of the Niagara Falls.

The discussions respecting the antiquity of man must be concerned with the number and nature of the subdivisions of the Quaternary. Were these two ages of cold separated by a warm period, or was the glacial climate connected with a single sheet of ice? Most of the relics of man found in this country are confessedly of origin subsequent to the later ice age, if it be granted that two existed. Some claim that man existed in the interglacial interval, and possibly earlier, because his relics occur in a deposit thought to be the equivalent of the earlier till, south of the terminal moraine, and called the Columbia formation. Dr. Wright has entered into the discussion of these questions, and, as already intimated, is not yet ready to accept the doctrine of the dual ice age. By necessity, therefore, his views of the Columbia formation are different from those of Mr. McGee, who first proposed the use of this name. Perhaps it will be well to state more fully the nature of these deposits and their relations to the moraines. The formation has been described by W J McGee in the "Report of the Health Officer of the District of Columbia" for 1884–85, printed in 1886; in several communications to the *American Journal*

*of Science*, 1886–88; before the American Association for the Advancement of Science in 1887; and in the "Seventh Annual Report of the United States Geological Survey." The name comes from its development about Washington, where it was first studied. The materials are gravel, sand, and loam, grouped in two divisions, of which the lowest consists of sand grains and boulders of mostly local derivation, while the highest consists of loam, rock-flour, and stones of various sizes of more remote origin. It makes its appearance upon the sides of the valleys of the Roanoke, James, Rappahannock, Potomac, Susquehanna, Schuylkill, and Delaware rivers, attaining the altitude of 75 feet on the Roanoke, and then respectively 100, 125, 145, 275, 500, and 400 feet upon the several others named. There is a correspondence between the size of the boulders and the magnitude of the deposits; i. e. the stones in the Roanoke beds are two or three times larger than those now transported by the river, while upon the Susquehanna the ancient boulders were fifty times larger than those now moved by the spring freshets in that stream. Upon the Potomac the boulders attain the maximum size of five feet in diameter. At the head of Chesapeake Bay the Columbia deposits reach the altitude of 240 feet, and are traceable up the Susquehanna until they pass between the terminal moraine in Berwick, Pennsylvania, the gravels being usually 250 to 275 feet above the river, and sometimes 500. There seems to have been a general level of erosion called a "base level plain"—five or six miles wide—near but below the terminal moraine, covered over by these Columbia deposits, and it is conceived that the loam and boulders were washed out from the older till long before the visible terminal moraine was pushed down from the north.

of the early gravels is one hundred feet less above the sea.

There is another phase of this formation called interfluvial, which seems to join continuously these several fluviatile deposits at their mouths. It overspreads the depressed plain bordering the Atlantic coast, and merges into the fluviatile beds on the one hand and the marine deposits on the other, and is regarded as synonymous with the well-known preglacial yellow gravel of New Jersey and Long Island, as described by Cook, Lewis, Merrill, and Britton, and may extend to an altitude of 400 feet in New Jersey, and 200 feet on Long Island.

It is believed by Mr. McGee that the fluvial and interfluvial phases merge into each other, all having been deposited beneath the ocean; that the river valleys were estuaries, and consequently that the land was depressed as indicated by the deposits, from 75 feet on the Roanoke to 500 on the Susquehanna; and that the Columbia deposits represent the aqueo-glacial margin of the first or oldest drift sheet, of which signs have mostly disappeared. Consequently it is inferred that the ice age was divided into two parts, separated by a long interval, when the climate was moderate, and that the early ice age was very far back, when measured by years.

Dr. Wright has well shown, in declining to accede to these views, that the fluvial Columbia phase is not distinguishable from the conditions producing the terraces of modified drift, as enunciated by Dana. The amount of material and the size of the boulders is greatest farther north; the slope of the deposits corresponds to that of the rivers; the presence of loam high up is like the clay in the Connecticut; the material has been drifted from the glacial moraines, and there seems also to have been a depression in the north, reducing the velocity of the currents. The question, therefore, arises as to the correctness of the observation that the Columbia beds extend beneath the terminal moraine. Dr. Wright accepts Professor Lewis's observations upon this point on the Delaware,

which do not agree with the Columbia theory. The Philadelphia brick clay is said by Lewis to gradually merge into the boulder clay, or till, of the ground moraine; while McGee, referring it to the Columbia formation, says that it passes beneath the terminal moraine. Further observation is therefore required for the settlement of the point in dispute.[1]

One would desire to direct the attention of those who are studying these Quaternary deposits to the following points: 1. In the scheme showing the relations of the deposits along the mid-Atlantic slope to those of the interior, the first glacial till is considered the equivalent of the Columbia, but there is nothing inserted to fill the long gap between the two tills. What are the deposits that must have been made in this long period? 2. The weight of authority indicates an elevation of the eastern part of the continent during the early part of the ice age, particularly off the mouth of Hudson River. Are we not to look for the early Quaternary marine deposits beneath the ocean off our coast north of Virginia? If the depression insisted upon came because of the weight of the ice-sheet, would this effect have been seen very early in the Quaternary? 3. According to Professor Lewis,[2] the terminal moraine

[1] Professor Lewis, after describing the Trenton gravel containing human implements and overlaying the brick clay, says of the latter: "As to the . . . brick clay, a still more remarkable change occurs at Belvidere. Losing completely its stratified character, it becomes a heterogeneous mixture of impure yellow clay, filled with both rounded and sharp stones, which are imbedded at all angles in the clay, and are frequently striated or ground down on their longer sides. Boulders are much more frequent in it and larger than they were south of Belvidere, and angular fragments of rock for the first time appear. But the most remarkable change is as to the limits within which the formation is confined. No longer bounded by a fixed elevation above the river, it occupies the hill-tops as well as the valleys, covering the whole region to the north as with a mantle. . . . . The *brick clay* has in fact become a boulder clay or *till*, having all the characters

crosses the Susquehanna at Berwick, at the height of 500 feet above tide water. Mr. McGee says that the older slackwater Columbia deposit rises 500 feet above the Susquehanna[1] before passing beneath the moraine. Is it not just as necessary to invoke a marine submergence for the deposition of the Columbia formation in Berwick as below the Kittatinny water gap? Why should there have been a difference of 100 feet on the submergence of the Susquehanna and the Delaware, especially as, according to the more northern latitude, the latter depression should have been the greatest? 4. It is said that the moraine is seldom completely oxidized, while the Columbia deposits are profoundly ferruginated, and hence the moraine is the newer of the two. Mr. Upham has distinguished the terminal moraine in Massachusetts and Long Island from the ordinary ground moraine by the fact of its greater oxidation. It is the development of the distinction insisted upon in the New Hampshire reports, therein following Torell for Sweden, that the lower part of the till is not ferruginated because it has been mostly secluded from the access of the atmosphere and water, having been accumulated beneath the ice-sheet; whereas the upper part, being made up of the fragments resting upon and in the ice, has been peroxidized through exposure; and the material pushed forward to the front of the sheet becomes colored just like the upper till for the same reason. Hence it is not always true that a reddish ferruginous till or gravel is necessarily of greater age than the bluish earths. The till, however, always derives its characteristic feature from the ledges which have been broken down for its manufacture. 5. If it be insisted upon that the older till is absent in Southern New England, the Pleistocene fossils of Gardiner's Island and Sankaty Head would represent a late epoch in the newer ice age, since they were barely reached by the ice-sheet at its extreme southern extension; and hence these are not to be synchronized with the Columbia. 6.

[1] American Journal of Science, Vol xxxv. (May 1888) p. 378.

As is indicated in our report upon the Quaternary to the London International Geological Congress, the true measuring-rod of this period is the marine Pleistocene of the Atlantic coast. It should be synchronous with the entire Quaternary, early, inter, and later post glacial epochs. The *Syrtensian* or Labrador fauna, extending as far south as Saco River, Maine, is coeval with the *Acadian* fauna extending to Point Shirley, Massachusetts, and the *Virginian* fauna prevailing from thence southward. Near the sea coast, as at Portland, Maine, the fossiliferous clays lie between two deposits of till, while farther north it overlies the till altogether, as if they were contemporaneous with the whole of the ice age.

It will be seen from these brief statements, that the order of the events in the Quaternary is not yet satisfactorily settled. Hence exact determinations of the age of relics of man found here and there are not practicable at present, though approximation may be made sufficient for a general reference.

Mr. Warren Upham has kindly prepared for this book several maps and an appendix upon the "Probable Cause of Glaciation." The Niagara estimates make him distrustful of the calculations based upon the eccentricity of the earth's orbit, which were so popular a decade since. Quite recently geologists are returning to the belief that the crust of the earth is comparatively thin, over a molten interior, and in the sensitiveness of the surface to deformation by weight and pressure. The transfer of a single foot of sediment from the upper to the lower part of a hydrographic basin is thought to cause a change of level through the disturbance of the equilibrium. Hence the accumulation of an ice cap thousands of feet thick is adequate to produce a considerable depression because of its weight. Before this depression, however, Mr. Upham

elevation along both of the continental borders. That this is not exceptional appears from the extensive Quaternary mountain building among the Himalayas, in Thibet, and much of Central and Northwestern Asia, as well as in South America, Cuba, and the Sierra Nevada. This elevation seems to have been the main cause of the increased precipitation of moisture in the higher latitudes and its refrigeration.

Significant changes of sea-level are necessitated by the abstraction of the moisture from the ocean and its transfer to the land, and by an attraction of the water by the ice. In the first case, he estimates a lowering of the sea to the extent of 150 feet; in the second case, he finds the sea would be depressed in the tropics from twenty-five to seventy-five feet, while the land near the ice-sheet would be raised enough to counterbalance the depression due to the removal by evaporation. Such indentations as the Pamlico and Albemarle sounds might have been carved out by stream-erosion when the ocean was thus lowered, while the formation of the Chesapeake and Delaware bays would have been channelled out at the same time with the excavation of the Hudson fiord.

Combined with the oscillations of the earth's crust, there may have been changes in aerial and oceanic currents and the revolution of the seasons due to the earth's cycle of 21,000 years through precession of the equinoxes and nutation. If this cycle is to aid us, we may say that the ice age culminated 10,000 years ago, and that it was preceded by another term of cold of 21,000 years previously. Mr. Upham is disposed to say one or two hundred thousand years when he names a probable figure for post-Tertiary time.

In conclusion it may not be amiss to call the attention of ministers of the gospel to the opportunities afforded them of pursuing the study of nature, subordinated to their appropriate duties. Many are so situated that long summer vacations are at their command, which have been

spent upon travel, hunting, or fishing, productive of recreation to themselves, but not of special profit to the world. To such, the example of Dr. Wright is to be commended. By devoting his vacations and odd hours to the study of glaciation for the past fifteen years, he has produced results of which any geologist might be proud. It is conceivable that a pastor might exert a more powerful influence upon some if it were known that he was an authority upon some scientific topic. In the study of surface geology in its bearing upon the history of man, it is well that there should be a few staunch theologians who could criticise any unfriendly and unwarranted conclusions. The ability to refute false positions is a plant of slow growth, and can be properly acquired only through careful study..

The number of clergymen who take delight in scientific investigation is large. The most of those interested have no thought of pursuing any special investigation. Some are so situated that their observations are recorded. Thus we have had numerous letters from the Rev. Titus Coan, of the Hawaiian Islands, detailing the varied appearances of the great volcanoes near Hilo. No history of volcanic action will be complete that overlooks his letters. Rev. E. P. Baker, of the American Church at Hilo, is following his example. Rev. J. T. Gulick, of Japan, a missionary of the A. B. C. F. M., is a known authority upon the subject of *Achatinella*, a family of land shells. He has found time to reflect upon the origin of species, and has recently published a memoir upon this subject worthy of mention beside the noted treatises of Darwin and Wallace. The late Rev. J. B. Perry, of Cambridge, was known as a successful student of the fossils and literature of the Cambrian system. Rev. H. C. Hovey, of Bridgeport, Conn., has given us our best account of the caves of this country. The example of these gentlemen is worthy of imitation. To go no further, the working out of the details connected with the ice age would be an enterprise adequate to enlist

the energies of a dozen energetic amateurs for the next decade. Let any such provide themselves with Dr. Wright's "Ice Age," President Chamberlin's papers in the "Reports of the United States Geological Survey," and any special report that may have been made upon the district or state in which they reside, and they will possess the literature needful to start them upon original investigations.