ART XXIX.—*Northward Extension of the Atlantic Preglacial Deposits* ;* by ISAIAH BOWMAN.

OUTLINE.

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INTRODUCTION.

HEAVY winter storms on the New England coast following the unusually dry autumn of 1904 resulted in many changes in coastal topography, among which were the rapid cutting back of headlands of soft material and the freshening of cliffs. Good opportunities were thus presented for the study of exposed geological sections. The Third Cliff section near Scituate, Massachusetts, is of special interest because of the lithologic and stratigraphic homologies between the exposed beds and preglacial deposits farther south and their bearing on the question of the northern limit of the Atlantic Cretaceous and Tertiary. The nearest known outcrop of deposits of Cretaceous age is at Gay Head, Martha's Vineyard, 52 miles south of Third Cliff; the nearest known deposits of Tertiary are the Miocene Greensands at Marshfield, 7 miles south of Third Cliff. The latter are not commonly known to occur though they were noted by Hitchcock† as early as 1841 (p. 91), the latest text-book of Geology‡ stating that "The northernmost exposure of the Miocene on the Atlantic coast is on Martha's Vineyard."

Third Cliff is one of a series of four cliffs in close succession twenty miles southeast of Boston and immediately south

* The suggestions of Professors Woodworth and Jaggard of Harvard and Professor Barrell of Yale University are hereby gratefully acknowledged. Special thanks are due Professor Jeffrey of the Harvard Botanical Laboratory for identifying the lignites.

† Final Report on the Geology of Massachusetts, vol. i, pp. xii to 831, 1841.

‡ Geology, Chamberlain and Salisbury, vol. iii, p. 260, 1906.

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of Scituate Harbor. They are represented on the Duxbury Sheet, U. S. G. S., as the eroded edges of drumlin-shaped hills, from 20 to 75 feet high and with major axes trending NNW. The accompanying sketch (fig. 1) of a part of Third Cliff depicts the chief features referred to in the following description.

Lithologic and Structural Features.

Preglacial Series. (1) *Basal clays.*—The basal member of the Third Cliff section is a layer of clay having the light yellow color of terra cotta. The top of the layer is about at the level of high tide, and an excavation of several feet failed to reach the bottom. It lies in a nearly horizontal position, with slight dip to eastward. It is extremely unctuous when wet and resists wave action to such a degree that

FIG. 1. Topography and structural relations of part of Third Cliff. Heavy continuous lines represent observed structures. Heavy dotted lines represent inferred structures. Horizontal scale = 175 feet to the inch. Vertical scale = 130 feet to the inch.

the height of the steeply-sloping boulder-strewn beach (fig. 1) is determined by its upper surface. Within the body of the deposit the clay is very pure, but towards the top becomes more sandy, containing round inclusions of yellow sands up to a centimeter in diameter. Lamination appears near the upper surface, at first faintly and then more strongly marked, changing finally into cross-bedded structure, although the bulk of the material is still clay. An 18-inch deposit of alternating yellow sands and clays, of several inches thickness each, completes this lowest member of the preglacial series. The entire layer contains muscovite in considerable quantity, and under the microscope shows an occasional grain of glauconite and scattered fragments of sponge spicules, none of which have sufficient character to be identifiable, although one specimen suggested a form of *Geodia*.

(2) *Yellow and white sands.*—A deposit of yellow and white sands lies conformably upon the basal clay, the latter color gaining predominance towards the top. Like the clays

beneath them, these sands dip gently to the eastward. Their maximum thickness is 25 feet, with, however, many variations in thickness, as will be explained in a later paragraph. But slightly cross-bedded at the base, these sands become more and more irregular towards the top, where they display excellent cross-bedded structure, the upper eight feet of the layer being exclusively of this character. The sands vary in texture from fine at the bottom to coarse at the top, and show in the same direction a decreasing amount of the clayey constituent possessed throughout. Just above the clays on which they rest the sands carry sufficient clay to render them somewhat plastic when wet. At the top of the sands where cross-bedding is most marked the sands are dry and partially indurated, so that the eroded edges retreat with a nearly vertical face. The indurating process has been carried so far in a few places that the material might almost be called a sandstone. Scattered fragments of sponge spicules occur here as in the clays previously described, and an equal amount of glauconite. The sands are very silvery in general appearance, owing to the great amount of muscovite present, some of the flakes attaining a size of from 4 to 6 millimeters. There is no break in the series thus far described, every change being slow with conformable relations throughout.

(3) *Red sands*.—At the top of the white sands an unconformity occurs, the eroded edges of the white sands being overlaid by a layer of coarse and dark red sands with a maximum thickness of 10 feet. These red sands bear large quantities of muscovite, a smaller quantity of biotite, and also exhibit cross-bedding of a much greater degree of amplitude than that shown in the white sands. Occurring only in patches between the white and red sands and never present where unconformable relations between these two members are exhibited, is a thin layer (1 or 2 feet) of black, coarse sand composed of large grains of smoky quartz and with an admixture of biotite. It is cross-bedded after the manner of the red sands which overlie it.

(4) *Dark green sands and clays*.—If fig. 1 be consulted, it will be seen that below the stairway near the middle of the figure the section shows greenish black sands and clays at the level of the white sands and below the level of the red sands. The whole face was so masked by talus and landslide material near the top of the bluff that extensive excavation was necessary to determine the relations of the various beds. Both series of beds were evidently in place and the problem resolved itself into finding the line of contact between the two. This was accomplished with the results shown in fig. 2, which is an enlarged portion of fig. 1 at E.

The white sands were found to exhibit in the clearest possible manner the erosion of a considerable body of their material, the entire series above them being swept away in addition. Upon their eroded edges lies unconformably a layer of white and yellow clays and sands which are superseded above by the greenish black clays noted in the section. The overlying dark clays and the yellow sands and clays between them and the underlying white sands, thicken gradually toward the middle of their outcrop (fig. 1), where the sands attain a maximum thickness of 3 feet and the clays 8 feet. These clays exhibit

FIG. 2. Representing unconformity between dark clays and white and yellow sands at E, fig. 1. Nos. 1 and 3 in diagram represent unconformities; at 2 the deposits are conformable.

the same changes as those of the lowest clays in the series—a gradual transition into more sandy members of similar color and 12 feet thickness, which completes the upper part of the preglacial section.

As soon as this relation between the beds was discovered the entire section was re-examined with a view to interpreting the relations which proved puzzling elsewhere, and in each locality, no matter how disturbed by ice action or disguised by landslides, the greenish-black clays and sands were always found upon excavation to overlie stratigraphically the white sands of cross-bedded structure.

Glacial Series.—The glacial material which overlies all of the preceding beds may be divided into two classes. The lowest is stratified brown sand bearing a high percentage of erratic material and occupying the eroded depressions in the lower beds; the second is a confused mass of red and white sands (see A, fig. 1) intermingled with erratic sands and typical boulder clay, the boulders attaining a maximum diam-

eter of 6 feet. The two classes of deposits are in unconformable relation to each other, and along the entire cliff face are seen to be in strong unconformity with the beds on which they rest (see B, C, D, fig. 1). The detailed structure of the till is shown in fig. 3, great blocks of bowlder clay being separated by a "filling" of horizontally stratified sand which, being without the slightest marks of disturbance since deposition, was deposited in water either contemporaneously with the till or later as a secondary deposit between the blocks of till as fast as the ice between the blocks was melted out. At Fourth Cliff similar structures are seen with a considerable part of the material derived from the preglacial beds eroded by the ice sheet in its advance. At Indian Hill, seven miles southeast of Plymouth, a good 85-foot section shows the further complexity of a layer of clay entirely different than any in the Third Cliff section, with a thickness of 20 feet and underlaid by erratic sand and gravel.

FIG. 3. Showing structure of till just beyond left margin, fig. 1. Sand between till blocks is cross-bedded and undisturbed. Figure represents area about 5 feet square.

This layer may represent an interglacial deposit or a deposit formed during a temporary recession of the ice. Its homologue does not exist in the Third Cliff section, nor is there any indication whatever at the present time of deposits or structures developed contemporaneous with those at Indian Hill. In all three sections there exists a thin layer of iron-stained reddish and apparently older till just above the stratified material of aqueo-glacial origin.

Succession of Events in the Deposition of the Third Cliff Beds.

The points to be considered in the determination of the age of the beds below those of glacial relationships will be better understood after their interpretation in terms of the events which they represent.

It appears that we have represented in the 40 or more feet of yellow clays and sands first described, marine conditions with a steady shallowing of the basin of deposition either through uplift or the gradual upbuilding of the floor through sedimentation. These conditions are marked particularly by the sand inclusions which occur on the top of the clays and the gradual transition of clay to sand with the upper part of

the sands strongly cross-bedded. There followed a period of erosion which may represent very shallow water conditions without actual exposure to subaërial processes. Currents and waves have already found expression in the cross-bedded structure and to their increased efficiency at this time may be attributed the unconformity in question. Then came the deposition of the black sands composed of grains of smoky quartz, followed by the deposition of the red sands. The slight thickness of the beds representing the intervals of deposition, together with their cross-bedded structure and present position and attitude with respect to other beds, and the existing shoreline favors the view that coastal changes were here of a less profound order than along the more southerly part of the Atlantic littoral, where extensive denudation followed the deposition of beds of great thickness.

Apparently the greatest erosion followed the deposition of the red sands. In many places the red, black, and white and yellow sands are entirely removed down to the basal yellow clays. In the depressions thus formed was deposited the greenish black clay of figures 1 and 2. Gradual shallowing of the deeper water in which the clays were deposited is represented by the greenish-black glauconitic sands at the top of the darker beds, figure 1.

The succeeding events of importance in the history of this part of the New England shoreline were the erosion of the whole series thus related and successive advances of the ice. The first effect of the latter process was probably the deposition of the brown erratic sands as a preliminary wash to be superseded by the deposition of the ice-borne clay and boulders. The relations of the glacial material were not considered in detail, as the field of observation was too limited. The explanation of the manner of deposition of the stratified glacial sands may therefore be erroneous when more extensive observations are made. The retreat of the ice left the surface of the till practically as we see it today, except where it is modified by shallow gullying or by the insistent attack of the sea.

The weight and movement of the ice upon the unindurated preglacial sands and clays below resulted in the bodily removal of great masses of these deposits. They are clearly seen in the face of the cliff surrounded by erratic sands and bowldery clay (A, fig. 1). In addition, the remaining sands exhibit ice disturbance, for while they are practically in situ they are minutely fractured and faulted as shown in the upper right hand corner of fig. 2. In every case the blocks are easily restored in thought to their original positions by the help of slight variations in color and texture. The openings between

blocks are filled in some cases by a silty deposit which can in every instance be traced up to the till or sand above, from which it was derived by percolating waters. The great boulders in the till are continually falling from the cliff face to the beach below and give added protection to the basal clays which determine the level of the beach. The clays, the partially indurated sands and the till—all alike possess sufficient tensile strength to stand in bold cliffs and thus yield under an encroaching sea a remarkably clean and perpendicular section.

Former Interpretations.

Both Third and Fourth Cliffs have been described by Upham.* As his interpretation differs widely from the one just given, the following summary of his results seems appropriate in this place. It should be said that the section is today in much better condition than when examined by Upham and probably shows the relationships of the various deposits very much more clearly than at any time heretofore.

The two cliffed hills are referred to as "two extraordinary drumlins . . . which consist of till . . . to a depth that varies from 15 to 25 feet . . . but below include beds of modified drift that attain in Third Cliff a thickness of at least 40 feet, reaching to the boulder-strewn shore" Neither the yellow clays which, partly masked by boulders, form the shore, nor the unconformities above and in the so-called modified drift were noted. That the material is not modified drift is shown by a wholly dissimilar structure and lithologic character; and by the total absence of erratic material, and a remarkably pronounced and persistent unconformity between the erratic and non-erratic beds, with several smaller unconformities within the latter (see conclusion, p. 325).

Upham speaks further of the anticlinal structure of the modified drift and the approximate coincidence of the upper surface of these beds with the surface of the till at the cliff top. This is offered as evidence of the manner in which drumlins are deposited underneath the ice, but in the better section of today the cliffs show in the clearest possible manner that the apparent anticlinal structure is in reality the effect produced by successive faultings of broken blocks of white and red sands as shown near the left margin of fig. 1; and that the coincidence or parallelism of the structural surfaces called anticlinal is due not to similar dynamic conditions imposed by the ice, but to the control exercised on ice movement and deposition by the form of the subjacent terrane. It cannot, therefore, be argued alone from the relations exhibited here that drumlins are a subglacial deposit built up by successive accretions from the debris-laden lower part of the ice. It is

* "The Structure of Drumlins." B. S. N. H. Proc., xxiv, 228-242, 1889.

not implied that such conditions may not have occurred elsewhere, but that such was not the case here is clearly proved.

The presence of the yellow sands was noted by Upham and also the lignitic clays, "laminated dark gray clay," the latter being attributed to deposition of material subglacially transported, the lignites being explained as the possible remnants of an interglacial forest overwhelmed by the ice, yet the absence of all bowlders and till fragments in the clays was observed. The better section of today shows also that the structure of the till is in reality like that shown in fig. 3, and not obscurely laminated. The same figure shows the presence of seams and lenses of gravel within the till, their absence having been asserted heretofore. The various anomalies, which Upham's observations led him to believe were present here, were explained by the suggestion that the modified drift of Third Cliff was deposited under very unusual sub-glacial conditions.

Occurrence of Preglacial Deposits near Third Cliff.

Deposits of pre-Pleistocene age once subaerially eroded and now submerged have been presumed by several writers to occur near shore on the floor of the sea north of Martha's Vineyard. The first to suggest this, with the possible exception of Hitchcock, who vaguely refers to this matter (p. 427), was Verrill,* who observed in dredged material from the north Atlantic coast compact calcareous sandstone and arenaceous limestone bearing fossil shells and fragments of lignite. About half the fossil forms were considered extinct. Verrill thinks that the fragments were probably "detached from a very extensive submerged Tertiary formation at least several hundred miles in length, extending along the outer banks, from off Newfoundland nearly to Cape Cod and perhaps constituting, in large part, the solid foundations of these remarkable submarine elevations."

Later on, Upham† reports finding fossils of possible Eocene or Cretaceous age in the drift materials near Highland Light, Cape Cod. Hitchcock‡ even believed from the Miocene deposits at Marshfield (seven miles south of Third Cliff) that deposits of Tertiary age occurred "abundantly along the coast from Marshfield to Plymouth and not improbably also on Cape Cod," although their actual occurrence was not noted.

Professor Shaler, in his report on the geology of the Cape Cod District,§ suggested the presence, at least on the sea floor,

* "Occurrence of Fossiliferous Tertiary Rocks on the Grand Bank and George's Bank." This Journal (3), xvi, pp. 323-324, 1878.

† Marine shells and fragments of shells in the till near Boston, B. S. N. H. Proc., xxiv, pp. 127-141, 1889.

‡ See footnote, p. 9.

§ "The Geology of the Cape Cod District," by N. S. Shaler, 18th Annual Report, U. S. G. S. Part II, p. 580, 1896-97 (see also pp. 516 and 578).

of Cretaceous and Tertiary deposits northward as far as Cape Ann, from the general likeness of the outlines of the shoals of Stellwagen Bank to Cape Cod and the relations of the now submerged valleys.* The suggestion, though a purely analogous one, is of great interest in the further exploration of the field concerned.

Correlation with Similar Deposits to the South.

The evidence upon which age determinations are attempted is gathered from a close study of the strata themselves and of adjacent areas. The paleontologic evidence secured does not have the specific quality demanded for the purposes of correlations, although none of the evidence of this nature negatives the conclusions reached by other evidence. In short, the conclusions rest upon presumptive evidence and must, therefore, be held as tentative and suggestive only.

Continuity of Deposits.—At Marshfield, seven miles south of Third Cliff, greensand beds were noted by Hitchcock as early as 1830.† Their age was later determined by Dr. Dall from fossil evidence and found to be Miocene. The deposit is highly glauconitic, occurs about up to 15 feet above mean tide level, and is in very close contact with the granitic floor, which outcrops two miles farther south. The sands do not outcrop, but are reached by excavating 6 to 8 feet beneath the surface. They were first discovered in digging for a well on the farm of Mr. Kent.

The presence of this bed suggested that coastal sections between Third Cliff and Martha's Vineyard might show similar deposits, but a search from Boston Harbor to Peaked Cliff, 15 miles southwest of Plymouth, proved fruitless except for the finding of drift material often in great abundance derived from preglacial beds undoubtedly similar to those at Third Cliff. This is particularly true of parts of the glacial deposits at East Marshfield, Kingston, Indian Hill, Lookout Point, and Peaked Hill. The unusual character of some of the glacial material in these places is very striking. There is a large amount of white and red sand rather poorly mixed with the more common brown sand noted in sections of glacial material farther inland. These suggest the wider extent of the preglacial deposits and their considerable erosion by ice.

Similarity of materials.—The fact that at least a part of these deposits were formed in relatively shallow water near shore, as shown by the cross-bedded structure of the lower sands, renders their correlation on this ground along with similar deposits on Martha's Vineyard insecure, because of

* See map of the Cape Cod District.

† "Final Report on the Geology of Massachusetts," pp. 91-95. and 427, 1841.

the varying physical conditions under which sedimentation takes place in shallow waters. Controlled by the evidence of the unconformities it has, however, a more certain value. The relative thinness of the deposits close to this, their northern limit, and the frequent unconformities point to even greater irregularity in the physical conditions here than farther south, the deposits being more readily affected by slight oscillations of level common to the lands. The complexity of the mutual relations of coastal deposits is enhanced by the fact that continued erosion and redeposition often results in the close lithologic resemblance of beds of quite different age. In such cases there is, therefore, small value in the conclusions based on evidence of this sort. Unconformities and fossil evidence are the closest available determinants under such circumstances, and it is quite largely on the former that the conclusions of this paper are based.

The nearest known outcrop of beds lithologically similar to those at Third Cliff is at Gay Head, Martha's Vineyard. These are described by Professor Woodworth,* who mentions the following characters of the successive beds:

Lower Cretaceous: non-marine, lignitic, leaf-bearing clays.

Upper Cretaceous: locally hardened bands of sands containing molds of fossils, locally developed beds similar to those at Indian Hill (M. V.) which have a texture varying from fine to coarse with scattered larger grains of quartz and abundant muscovite scales. Inferred unconformity between Lower and Upper Cretaceous.

Miocene: thickness varies from 0 to 10 feet. Consists of two members—osseous conglomerate and foraminiferal or greensand beds, with unconformity between. The former is from 12 to 18 inches in thickness, consists of rounded boulders or of nut-sized quartz pebbles white and well-rounded. Cetacean bones present. The foraminiferal bed is from 0 to 10 feet thick, green color below, brown above, basal part includes rolled fragments of osseous conglomerate and bears glauconite casts of *Macoma lyelli* in the attitude of growth and the crab *Archeoplox signifera* in lower part of stratum.

Probable Pliocene: yellowish green and brownish clays bearing glauconite and Pliocene fossils. Inferred unconformity between Pliocene and Miocene.

The paucity of glauconite in the Gay Head Upper Cretaceous and the variable texture of the material, the scattered quartz grains, abundant muscovite scales, correspond precisely with the conditions found in the white and yellow sands which form the basal member of the Third Cliff section. Even the occurrence of cross-bedding on a small scale in the coarse pre-

* "Unconformities of Martha's Vineyard and Block Island"; B. G. S. A., viii, 197-212, 1897.

Tertiary sands (p. 200) is noted. Were lithologic identity alone a determinant in correlation, we should be completely justified in calling these beds Upper Cretaceous. The irregularity of the New England shoreline, and the considerable distance (52 miles) between Third Cliff and Gay Head, make it probable that the physical conditions under which sedimentation took place were not persistent throughout the entire district, and it is, therefore, not surprising that at Third Cliff there should be present a layer of red sand cross-bedded throughout on a large pattern which does not appear in the Gay Head section. With this exception the beds overlying the first unconformity at Third Cliff are again similar to those at Gay Head, except for the osseous conglomerate which is not present at Third Cliff, but the glauconitic sands are present bearing the white well-rounded quartz pebbles. Moreover, these beds are at precisely the same altitude as those definitely known to be Miocene (p. 321) at Marshfield, seven miles south. The Marshfield beds rest upon granite, the dark sands and clays of Third Cliff upon white sands. On the whole, the relatively close agreement of unconformities and lithologic characters seems very striking. While this resemblance, as was noted on the preceding page, may have slight value on account of marginal redeposition without the destruction of characteristic features, it is in a measure significant on account of the distinctness of the separating planes in the deposits and the strongly marked individual character of each bed. It is the more convincing to one who has seen the Atlantic Cretaceous and Tertiary farther south and has noted the persistent and distinctive character of these deposits.

It would be quite unsafe to base a correlation of the Third Cliff deposits with those of New Jersey entirely on the evidence presented here, but it is not without interest to note that with a single exception the Red Bank sands occur exclusively in the Monmouth formation, Upper Cretaceous, "except in certain marginal phases of the Rancocas formation,"* which latter is itself of Upper Cretaceous age. Glauconite occurs in great abundance in the Upper Cretaceous of New Jersey, and but sparingly at Gay Head, and certain yellow sands are found alike in the Miocene and Upper Cretaceous.

Paleontologic Evidence.—A fourth probability is suggested by the studies of T. C. Brown of Columbia† on the Chappaquiddic fauna from Martha's Vineyard. A comparison of this fauna with the Eocene faunas of the Atlantic and Gulf provinces indicates that the species closely resemble those

* Upper Cretaceous Formations of New Jersey, W. B. Clark; B. G. S. A. viii, 313-358, 1896-97.

† A New Lower Tertiary Fauna from Chappaquiddick Island, Martha's Vineyard, Science, New Series, vol. xxi, No. 548, pp. 990-991, 1905.

found in the lower Eocene, and they are accordingly designated as lower Eocene. The fossils are found in ferruginous concretions, reassorted and deposited in their present position as glacial drift. They have apparently been moved from the north, probably from the sea bottom, and raise the question as to their relation to the Third Cliff deposits. Their relation is, of course, obscure at present, although future dredgings and soundings may throw some light on the subject.

As has been noted before (p. 321) fossil evidence is almost wanting. The sponge spicules, as already noted, were not identifiable with any degree of certainty. Their value even when identifiable is rarely great. The impression of a single bivalve was noted in the red sands, but as only the rounded and partly obliterated outline was visible it also proved of no value. Fortunately the green glauconitic sands in the upper part of the preglacial series are lignitic and a number of excellent specimens of pyrrhotized lignite were obtained. These were carefully examined for me by Dr. E. C. Jeffrey, of the Harvard Botanical Laboratory, to whom I am greatly indebted for a statement of his conclusions, based on extensive comparative studies of lignites from Martha's Vineyard, Staten Island, and Germany. Dr. Jeffrey states:*

"The lignites from the cliffs at Scituate . . . belong to an ancient type of Pityoxylon, earlier than that found in connection with the Baltic (Oligocene) amber. They closely resemble, although are not identical with, Pityoxylon from the Cretaceous beds of Staten Island and Martha's Vineyard, and are of the same general antique type. . . . all of the material belongs to one species . . ."

The fact that but one species was identified makes correlation based on the above determinations quite insecure. From the paleontologic evidence the deposits might be placed anywhere between the lower Cretaceous and the Pliocene with probabilities pointing to Eocene or Oligocene. On the other hand, the lithologic and stratigraphic evidence coupled with the geographic position of the deposits with respect to the Marshfield greensands points to their Miocene age.

In general, plant remains are known to have a low value as time markers in the geological column, especially such low forms as Pityoxylon† and allied species. The presence of the former is therefore to be considered not as confirmatory but as presumptive evidence which does no violence to the conclusions based on stratigraphic grounds.

Conclusion.

The conclusions reached after an examination of the foregoing evidence may be stated as follows:

* Personal letter, March 5, 1906.

See Palaeophytologie, Schimper and Schenck, p. 874.

(1) The lower part of the Third Cliff section is preglacial. This is based on the character of the deposits, the entire absence of erratic material, and the relation and sequence of the unconformities. The suggestion that these beds may be interglacial is opposed by a number of facts which point to the improbability of this occurrence. In the first place, two marked unconformities such as occur within the lower deposits, together with the individual character of the different beds, indicate a distinct even if small change in the conditions of deposition which one would expect should be marked elsewhere by deposits of a similar nature. No interglacial deposits of this character are known on the Atlantic coast. It would be singular, though not impossible, that an interglacial deposit of this thickness should elsewhere be swept away, a single remnant preserved in this locality only. It is more reasonable that extensive Cretaceous and Tertiary terranes should be removed leaving here and at Marshfield and Gay Head remnants of a similar nature. It would be very peculiar indeed if an interglacial deposit were to simulate so closely the stratigraphic succession and lithologic qualities of beds of known Cretaceous and Tertiary age, and at the same time be the sole representatives of their kind on the coast. To this fact we may add that the oldest known bowlder bed in New England is present here (see p. 317) and that it occurs above the unconformity represented at C, fig. 1, that is to say, above the most marked unconformity of the whole section and one which represents the most profound break in the conditions of deposition.

(2) The occurrence of Cretaceous and Tertiary deposits at Martha's Vineyard, 50 miles south of Third Cliff, and of Tertiary deposits at Marshfield, seven miles south of Third Cliff, make it seem not unlikely that deposits of the same age once extended farther north, as well as farther inland, though subsequent erosion may have all but completed the removal of such deposits.

(3) The similarity of the material and the many points of similarity of sequence in these several places indicate the strong possibility that the Third Cliff beds are to be correlated with those farther south.

(4) The identity of plant remains offers the same possibility based on an independent line of evidence.

(5) The convergence of independent possibilities renders the following more than *possibilities*: they may be accepted as *probabilities*:

(a) The underlying yellow clay and the yellow and white sands are considered as probably upper Cretaceous. (b) The overlying dark sands and clays are probably Miocene though possibly Eocene or Oligocene.