ART. XLV.—*The Geology of Block Island;* by O. C. MARSH.

A RECENT visit to Block Island gave me an opportunity to examine its geological structure, and this proved much more interesting than the published accounts had led me to expect. I had previously seen this island only from a distance, yet I supposed from what I had read that it contained none of the older rocks in place, but was a remnant of the great terminal moraine that, in the glacial period, was pushed over from the main land of southern New England, and left its debris as Long Island and the other islands to the eastward.* That Block Island was once connected with Long Island is suggested by a glance at a map of the New England coast, and that the same great moraine extended over both is equally evident from facts well known. An examination of Block Island itself, however, soon proved to me that these glacial deposits were merely a superficial covering, while the main body of the island was formed of much older beds, the exact age of which offers a most interesting problem.

These lower strata consist mainly of massive beds of clay, more or less arenaceous, and all considerably disturbed. The general inclination is to the northeast, as is well shown in the fine sections exposed on the coast, especially in the bluffs on the east and south of the island, which are rapidly wearing away from the assaults of Atlantic waves. Some of these clays are white in color, as seen in the cliffs at Clay Head, on the northeast shore of the island. Some bright-red clays also occur near the water's edge at low tide, at the foot of the same bluff, but the most of these deposits are gray or brown in color. At a few points, where carbonaceous matters have discolored them, they are nearly or quite black, and in such places, specimens of fossil wood and other plant remains are comparatively abundant. One locality of this character may be seen in a bluff on the southeast shore, a short distance west of the Ocean View hotel. Another marked character of these clay cliffs is the deposits of iron they contain. This ore is mainly limonite, usually in thin seams, and its decomposition has stained the layers in many places a rusty color, which frequently serves to indicate the dip of the strata. Iron pyrites occurs in the dark clays with the plant remains.

These massive beds of clay, with their characteristic features, are well shown in all the high cliffs of the coast that are being rapidly eroded by the ocean storms. The famous Mohegan

*Seventh Annual Report U. S. Geol. Survey, p. 304, 1888; and Bulletin U. S. Geol. Survey, No. 53, p. 11, 1889.

Bluffs, on the southeast shore of the island, afford a fine example of this, as here the clays show a vertical thickness of about a hundred and fifty feet. Judging by the inclination of the beds, which are highly inclined, a great thickness of strata is here represented. This fact, together with the disturbance they have undergone, is an important element in the problem of their age, and indicates for them a much greater antiquity than would otherwise be supposed from the nature of the deposits themselves.

These foundation clays of Block Island were evidently much eroded before the glacial drift was spread over them. They still constitute the bulk of the island, and their depressions form an impervious stratum for the bottom of the numerous ponds for which the island is renowned. These clays all appear to be fresh-water deposits, and should certainly contain vertebrate fossils. I found none in the limited time at my command, but more careful exploration would undoubtedly bring them to light, and thus determine the geological age of these interesting beds. In the mean time, a comparison of various deposits at some other points on the coast may, perhaps, suggest a solution of this problem.

In exploring the Tertiary and Cretaceous strata of the Atlantic coast south of New York, I have had much experience, but know of nothing in these two formations there exposed that offers a parallel to the deposits now under discussion. The still older Potomac beds, however, have many similar features, and to this horizon I should be inclined, on present evidence, to refer the greater portion, at least, of the Block Island clays. From the Potomac formation in Maryland, I have secured a large collection of fossil vertebrates that indicate a period corresponding nearly to the Wealden of England, which is now regarded by the best authorities as late Jurassic, and to this age the vertebrate fossils of the Potomac may likewise be assigned.* The special horizon in which these vertebrates are most abundant in Maryland may be called the Pleurocœlus beds, from a genus of Dinosaurs found there, especially in the iron-ore clays, which are similar in physical characters to some on Block Island.

The Raritan clays of New Jersey, I regard as belonging to the same series as the Potomac beds, since they hold the same relative position stratigraphically, while the only vertebrate fossils thus far reported from them (remains of a Dinosaur and a Plesiosaur, both preserved in the Yale Museum) also tend, in part, to confirm this view. The latter is probably from a higher horizon.

* This Journal, vol. xxxv, p. 90, 1888. See, also, Sixteenth Annual Report U. S. Geol. Survey, Part I, p. 183, 1896.

The well known clay deposits of Long Island I have not carefully examined in place. There is much in the published descriptions of them, however, to indicate that they may represent some of the same Jurassic beds. Near the eastern end of the island, there are beds of clay closely resembling some on Block Island.

The clay bluffs at Gay Head, on Martha's Vineyard, have many characteristics of the same series, but the presence of Cetacean remains in one portion of them indicates that this is Tertiary. There are, however, some reasons for supposing that the most of the clays are much older, and I believe they contain representatives of the same great Jurassic formation. Some of the vertebrate remains from Gay Head, described as Reptilian (*Graphiodon*), I found on examination to be Cetacean, and it is possible that others, now regarded as Cetacean, may prove to be Dinosaurian, as was the case with some Potomac fossils.

The massive clay beds of Block Island were derived from the decomposition of the granitic rocks to the north, and were deposited in quiet waters. The iron ore now in them came also from the northern crystalline rocks mainly as magnetite, which may still be seen in the sands of all the beaches of the island, and on one of them this mineral sand was for a while used in making metallic iron.

There appear to be no crystalline rocks in place on the island, although some of the large imbedded boulders might readily suggest such outcrops. The glacial drift covers most of the surface, and the hills and shores are strewn with boulders of crystalline rocks,—granite, gneiss, quartz, etc., that came over the ice from the main land on the north. Large masses of both the porphyritic and the garnet-bearing gneiss, waifs from the Rhode Island shore, may be easily recognized, and in the beach sand resulting from the attrition of the latter, the separate garnets may be found.

On some of the glacial hills near the shore, or around the Great Pond, shell heaps of considerable antiquity may be observed, but so far as I could ascertain, none of them have been explored. One may be seen on the south side of the road recently cut through a low hill, near the new steamboat landing on Great Pond. The deposits are several feet in thickness, indicating a long occupancy of the place by some of the early inhabitants of the island. The short examination I was able to give this "kitchen midden" disclosed many marine shells, mainly species now living in the adjacent waters, the most abundant of which were those of oysters, clams, and scollops. Mingled with these were a few bones of fishes, birds, and small mammals.

The presence of such great masses of stratified clay, evidently of high antiquity, on this diminutive island facing the Atlantic, opens up many questions of interest beyond the mere geological age of the deposits. These beds of clay must be the remnants of a great formation, which extended out far beyond the present coast line, and being of fresh-water origin and laid down in quiet waters, they prove the former existence of an extensive barrier along the continental border between them and the Atlantic depths beyond.

It has long been a reproach to American geologists that they could find no true Jurassic on the Atlantic coast, although the next formations above and below are well developed at many points. May not the missing strata be represented in the characteristic series of Block Island clays? The evidence as it stands to-day points to this conclusion.

New Haven, Conn., September 5, 1896.

Postscript.

Since the above was in print, I have visited Long Island and Martha's Vineyard to ascertain if the Block Island clays are represented there, as they should be if my conclusions are correct. On Martha's Vineyard, I found that the great series of variegated clays forming Gay Head, and generally regarded as Tertiary, are certainly Mesozoic, and all apparently Jurassic. They have the same general features as the Block Island clays, but are more highly colored, and have been more disturbed. They, also, suffered much from denudation before the Glacial period.

Prior to that period, however, they were covered by a series of marine Miocene deposits, remnants of which still rest unconformably upon them. The vertebrate fossils reported from Gay Head were apparently all from this horizon, which also contains many mollusks.

The cliffs of Gay Head are rapidly washing into the sea, the base being first undermined by storms, causing very extensive landslides which have led to much confusion in regard to the natural position and mutual relations of the various strata.

On Long Island, I visited a number of localities, including Montauk Point, where there are clay beds similar to those on Block Island, although possibly of somewhat later date. Other preglacial freshwater clays at various points on the north shore appear to be of the same age as those at Gay Head. I hope soon to discuss this subject more fully elsewhere.

New Haven, Conn., September 21, 1896.