ART. XVIII.—*The Central Massachusetts Moraine* ;* by
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UPON the plains of the Central States the ice of the last glacial period has registered, with distinctness, the various halts in its recession. The record of the ice retreat in this region has been worked out in admirable detail by the glacialists in charge of this work. Rapid retreats, temporary halts and slight readvances are here indicated by the glacial deposits.

The disappearance of the ice from New England must have been marked by very nearly the same history, but the detailed record of this retreat has not yet been studied. This is due in part to the fact that until recently no systematic studies of the glacial deposits of New England have been undertaken, but chiefly to the fact that the record left by the ice, as it melted away, is obscure. This obscurity is the result of the topographic diversity of the region. Upon a plain a slight moraine becomes a marked topographic feature, but amid the hilly district of New England its importance is masked by the more striking undulations and reliefs. In addition to this the very fact of the diversified topography has made the minor moraines actually less distinct and hence more difficult to study than would have been the case on a level country. The ice margin must have conformed in a measure to the topography, and hence the deposits must have varied in distribution with the variations in altitude and relief. Not only was their distribution so influenced but also their character. The rapid water currents rendered possible in a hilly country swept away portions and modified others.

For several years Prof. N. S. Shaler has been conducting detailed studies of the glacial deposits of Massachusetts and the neighboring states and eventually, if his plans are carried out, the record of the ice retreat in this region will be definitely known. As an assistant in this work during several summers it was my fortune to find and trace out, in part, a distinct morainal band in Central Massachusetts, marking a temporary halt in the recession of the glacier, and it is this that I shall briefly describe.

On the islands off the southern coast of New England a well defined terminal moraine has long been known and well de-

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scribed by various observers. It seems to be established that this moraine marks the point of the glacier for the greater part of its long stand upon this part of the continent. Patches of morainal matter have been noticed and described from various parts of New England, by Mr. Upham and others, but no continuous lines of moraine have been traced for any considerable distance. Some of these morainal patches have been supposed to mark local glaciers remaining upon the higher lands after the main ice mass had disappeared.

A singular morainal area was described by Prof. Shaler in the Ninth Annual Report of the U. S. Geological Survey, as occurring at Cape Ann on Massachusetts Bay. As an assistant in this work my attention was called to this deposit several years ago and its boundary within the area was traced with considerable accuracy. At that time it was not known that this bit of moraine was connected in any way with any other, but subsequent studies of the glacial deposits have pointed to a somewhat continuous moraine from Cape Ann nearly to the Connecticut River. Beyond the Connecticut morainal deposits have not been identified with certainty, excepting in some of the larger stream valleys; and the connection of these apparently isolated moraines with the Central Massachusetts moraine has not been definitely established.

The Cape Ann moraine has been fully described by Prof. Shaler,* with numerous illustrations from photographs. In general it occupies a large part of the island of Cape Ann and of the mainland to the west and southwest. On the island it covers the major part of the interior, but is rarely found in perfect development below the one hundred foot contour line, this part of the island being chiefly bare bed rock as if wave-swept. The morainal boundary is roughly circular, with an average diameter of not more than four miles. It is completely separated from the moraine on the mainland to the westward by the inlet or "reach" of "Squam River," but above the one hundred foot contour line it begins again occupying a wooded strip, with a width of from one to four or five miles, in the towns of Manchester, Essex and Gloucester. Farther still to the west the moraine becomes narrower but is distinctly traceable in the vicinity of Chebacco Pond, Wenham, and farther west to the extreme boundary of the Salem sheet of the Massachusetts topographical atlas.

This band of moraine is twenty miles long, and the width varies from a few hundred yards west of Wenham to four or five miles east of that town. The average width is not less than a mile. From the western part of the Salem street to

* Ninth Annual Report U. S. Geol. Survey, pp. 529-611.

Ayer Junction, a distance of twenty-four miles I have had no opportunity for studying the surface geology, but just southeast of Ayer Junction distinct morainal deposits are found and a quite continuous band of moraine extends from here westward to the Connecticut river, passing south of Winchendon, Royalston, Orange and Turner's Falls. This line of moraine is fifty miles long and thus from Cape Ann to the Connecticut, a distance of ninety-four miles, moraine has been found in seventy miles, the remaining twenty-four not having been examined.

To briefly describe the Cape Ann moraine it may be said that the essential features are sharp peaks and hummocks of drift, completely enclosed kettle-holes of unstratified drift, and a surface thickly strewn with boulders chiefly of granite locally derived. While the entire surface is boulder strewn, the most excessive development of bowldery deposits is in trains, or parallel bands extending a little north of east at right angles to the direction of glacial motion. There are several square miles of such bowldery places on Cape Ann where the boulders are literally piled one upon another with rarely any soil showing. A better development of the "bear-den" moraine would be difficult to find. Parallel with these boulder lines are ridges of drift and the corresponding valleys.

While the material composing the moraine is considerably less clayey than ordinary till it is, with rare exception, an unstratified deposit quite closely resembling till. A few patches of stratified drift and a single serpent kame occur on the island.

On the mainland west of Cape Ann much the same character marks the moraine, except that boulders are less numerous, as long as the moraine rests on the granite. Where it is found upon the metamorphic rocks as in Wenham and westward the boulders decrease perceptibly in abundance and size, the deposits are more sandy and they merge more commonly into stratified deposits. At the same time the distinctly "shoved" moraine narrows. These facts are undoubtedly to be referred in part to the change in character of supply, but chiefly to the more moderate relief which permitted the deposition of sand and gravel deposits. Some of the morainal peaks are partly buried beneath such deposits.

In the region between Ayer Junction and the Connecticut River the morainal accumulations are quite puzzling. The country is hilly and deeply scored by both east and west and north and south valleys. The result has been a complicated distribution of the morainal deposits which renders exact statements concerning the detailed history of their formation quite

impossible at present. The distribution is in more or less continuous patches; but distinct lines of moraine cannot be traced for any considerable distance, their continuity being interrupted by the irregularity of the topography. As the result of this we find a series of scalloped, serrated lines in the general moraine. These lines and the entire moraine are sometimes broken, yet the general continuity of the deposit is undoubted, for the breaks are rarely a mile in length.

A vacillating condition at this place is indicated by the great width of the morainal deposits. The moraine-covered tract is often eight or ten miles in width and isolated patches of "shoved" moraine are found both to the north and south of this.

The central Massachusetts moraine is typically developed at Winchendon, Gardner, and south of Athol and Orange on the Winchendon and Warwick sheets of the Massachusetts topographical map. A detailed description of the moraine on the various sheets will be found in Prof. Shaler's forthcoming monograph on the Surface Geology of Massachusetts. It presents all the features of a typical "shoved" moraine, being rough in outline and boulder strewn, having hummocks and kettles of unstratified drift and being associated with stratified drift both of contemporaneous and subsequent origin. This stratified drift is of the sand plain, esker and valley drift types. In places the morainal hummocks are made up of roughly stratified layers of till and gravel, they are at times partly and even entirely covered by stratified drift of the overwash type, and sand plains are not uncommonly found amid the morainal peaks and kettles. No distinct frontal apron exists, for the diversity of the topography would not admit of such well defined level deposits.

These observations prove that the ice halted in its retreat from New England at about the line occupied by this moraine. The halt was not of sufficient duration to permit of the formation of a strikingly well defined moraine yet it was long enough for the formation of a well defined morainal band. The varying width in the central part of the State points to some vacillation in the ice front at this place, though this does not seem to have been the case in the eastern part of the moraine near the coast line.

One of the striking features of the central Massachusetts moraine is its east and west course, since its linear extension is in general direction slightly diagonal to the glacial striæ. This is particularly the case in its sea coast end where it can be traced continuously for a score of miles nearly due west, whereas the striæ point usually N. 25 W. or even more. Even

in the interior the moraine does not swerve to the southwest showing that the highlands of the northern central part of the State and of New Hampshire exercised little influence upon the ice front. It may be said, however, that the glacial striæ in this part of the State point nearly north and south, the southeasterly trend near the sea coast being very likely due to the influence of the easterly sloping coast border.

Since this moraine has not been traced west of the Connecticut nothing can be definitely said with regard to its westerly continuation. It seems probable, as suggested to me by Prof. Dana, that the influence of the very marked highland region of the Berkshire Hills in Western Massachusetts must have caused a southward extension of the ice margin west of the Connecticut. In the region about Pittsfield and North Adams, particularly in the larger valleys, there are patches of bowldery, hummocky, partially stratified drift which seem to be morainal in character. No attempt can be made to correlate these with the central moraine at this time.

It is hardly probable that between the Long Island moraines and that of central Massachusetts the recession of the ice was so uniform and rapid that no sign of its retreat was left and the facts in the field seem to show that this was not the case. My studies have been in the main in isolated districts in Massachusetts, Connecticut and Vermont, so that aside from the moraine just described it is not possible for me to state definitely that other bands of moraine exist. Still, both south and north of this moraine, I have found isolated patches of true shoved moraine, though nowhere has it been found to have the well marked development noticed in that of central Massachusetts. Such deposits have been noticed in the vicinity of Worcester, Mass., in southeastern Massachusetts, Waterbury, Connecticut and southern Vermont, and other observers have described moraine in New Hampshire.

None of these deposits have been studied in detail and with a view to their relation to one another, but without doubt, when they are so studied it will be found that the history of the disappearance of the ice sheet from New England was, like the ice of the upper Mississippi valley, one of numerous halts and slight readvances, though the records left will be found to be much less distinct in New England than in the west.