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CERTAIN EXTRA-MORAINIC DRIFT PHENOMENA OF NEW JERSEY.

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PREVIOUS OPINIONS CONCERNING THE DRIFT MARGIN.

The terminal moraine running across New Jersey from Perth Amboy to Belvidere, and continuing thence across Pennsylvania, was first traced out under the auspices of the surveys of these states. The work in New Jersey preceded that in Pennsylvania, and was among the earliest morainic studies. In both states the terminal moraine referred to was published as representing the limit of glacial drift, and this conclusion, announced by the surveys of the respective states, was accepted by geologists as correct.

Interpreting eastern phenomena by western, glacialists not intimately familiar with the eastern field regarded the southern portion of the New Jersey and Pennsylvania drift as belonging to the first glacial epoch. The fact that the glacial drift of the interior is not limited on the south by a terminal moraine was well known, and the southern limitation of the eastern drift by a terminal moraine seemed to put the two regions in sharp contrast. But it was believed that if the known moraine of New Jersey and Pennsylvania represented the southern limit of the drift, other

moraines would be found toward the north equivalent to those of the interior, and referred to a later ice epoch. Subsequently, when glacialists familiar with the phenomena of older and younger drift sheets as developed in the interior came to study the drift of the states in question, the terminal moraines of New Jersey and Pennsylvania and the drift north of it were found to correspond in all essential points with the later glacial drift of the interior instead of with the earlier.

Still proceeding on the belief that the moraine represented the southern limit of the drift, it was inferred that the ice-advance of the later glacial times was equal to or exceeded that of the earlier, and that therefore the deposit of the latter was overridden and obliterated or obscured by the former. This interpretation, however, has never seemed entirely harmonious with the accepted interpretation of the drift phenomena of the interior. President Chamberlin has more than once expressed the opinion, though he has nowhere published it, that there might be an older drift sheet south of the moraine in New Jersey and Pennsylvania which had escaped observation. Two years since, with this suggestion in mind, though primarily for another purpose, President Chamberlin and the writer made a cursory examination of certain extra-morainic areas in New Jersey and Pennsylvania. The result of this examination was to strengthen the suspicion that glacial drift did not find its southernmost limit in New Jersey and Pennsylvania along the line of the moraine.

The phenomena which were then observed have never been published. The most significant fact developed was the existence of glacially striated stony material many miles south of the moraine at one point at least in New Jersey and at three points in Pennsylvania. The striated stones were occasionally seen to be embedded in a matrix of clayey nature, resembling till. This bowldery clay was of such a character and in such positions as to make the suggestion of its derivation from the moraine toward the north unsatisfactory if not altogether untenable. Some of the phenomena seen were capable of explanation without supposing glacier ice to have been present in the region where they occur; others seemed to us to find their most rational explanation in the supposition that glaciation had extended beyond the limit hitherto assigned it.

In June of the present year the writer visited New Jersey, and then learned for the first time that Professor Smock had long entertained the idea that there might be a formation of glacial drift south of the moraine which he had traced across the state. Professor Smock was in possession of a number of facts concerning the character of the surface formation south of the moraine which afforded sufficient basis for the idea which he entertained. When the writer undertook the detailed study of the Pleistocene formations of New Jersey a little later in the season, Professor

Smock very generously put these facts into his possession. Their nature was altogether in keeping with the facts which President Chamberlin and the writer had independently discovered two years since, and Professor Smock's inferences corresponded with our own.

Results of recent Studies.

Critical Localities and Exposures.—During the months of July and August, 1891, the localities which had raised the question of an extra-morainic glacial drift in Professor Smock's mind were visited by the writer and examined in detail, and many other localities were found where the same class of phenomena are to be seen. Some of these localities, because of their geographic positions and relations, seem to be crucial so far as the question of extra-morainic drift is concerned; and although the work on the Pleistocene formations of New Jersey is but begun, a few of the facts already developed are thought to be of sufficient importance to warrant statement before this Society.

At Oxford Furnace, at an elevation of between 500 feet and 600 feet, there is an accumulation of surface material which is certainly not of local origin. It is partly stratified and partly unstratified. It contains large bowlders of various kinds of rock, many of which show unmistakable signs of ice wear. They are so associated with clay that the unstratified portions of the material have the aspect of till. The relation of the stratified to the unstratified material is such as may often be observed in glacial drift.

This locality is not more than two miles south of the terminal moraine, and its altitude is slightly less than that of the moraine. Since this is the fact, and since the material is in part stratified, it might be inferred that the surface materials at Oxford Furnace are nothing more than derivatives from the moraine; but a critical examination of the material itself is fatal to this hypothesis. If this material were derived from the moraine by the action of water (an hypothesis which has found currency for similar formations similarly disposed elsewhere) its origin should be revealed in its structure and composition; but both its structure and composition show that it is not overwash material. Much of it is unstratified, and the relation of the stratified to the unstratified parts is most complex and not within the power of water, acting alone, to produce. Overwash gravel plains flanking the moraine are well developed in the vicinity, and their constitution and structure are well known. They consist uniformly of water-worn gravel mingled with sand. Earthy material is wanting. The unstratified material at Oxford Furnace, on the other hand, is a tough bowldery clay with its stony material abundantly striated, and

the striæ are of such a character as to make their glacial origin evident. Even among the pebbles of the stratified portions of the Oxford Furnace deposits, striated pebbles may occasionally be found, indicating that the materials have suffered but a limited transport by water. Furthermore, the relations of the stratified and unstratified materials are such as to show contemporaneity of origin.

In another sense the morainic material and the material of morainic derivation just north of Oxford Furnace are essentially unlike the Oxford Furnace deposits. The one bears every evidence of youth, and the other as strikingly bears evidence of age. In the one case the clays are unoxidized and unleached, and the stony material retains the hard fresh surfaces which characterize freshly glaciated bowlders. Even the sands, readily percolated by water, are calcareous to within three or four feet of the surface. In the other case, the clays are oxidized to great depths, the calcareous material which they presumably contained has been leached out, and a large proportion of the decomposable rock materials which the clay contains have so far yielded to the effects of weathering and solution as to have lost their integrity altogether. So striking are these differences in the two classes of deposits, good exposures of which may be seen within two miles of each other, that it cannot escape notice even in a cursory examination. If 1 represent the age of the material of the moraine, the age of the other can hardly be represented by one figure.

The higher lands southwest and west of Oxford Furnace are likewise found to be interruptedly covered by a similar drift mantle. It is generally absent from the steep slopes, is frequently present on the gentler ones, and is nearly uniformly present on the level summits. Rising from 550 feet near Oxford Furnace to 600, 700 and 800 feet, the same till-like material occurs. Near Little York, about 860 feet above tide, the same bowldery clay is exposed to a depth of ten feet or more. The stony material is predominantly small, and the larger portion of the stone is of quartzite or hard sandstone. The quartzites and hard sandstones do not commonly show glacial markings, though their surfaces are generally unweathered and sometimes show planation. The fragments of crystalline rocks (crystalline schist series) are almost uniformly so far disintegrated that they would not show surface markings even if once present.

Among the stony ingredients at this place there are many bits of soft shale. With these the case is very different. These bits of shale, soft as they are, have withstood the disintegrating action of air and water, and very many of them still preserve the surfaces they possessed at the time of their deposition. Among the fragments of shale, large and small, it

is well nigh impossible to find a piece which still preserves its original surfaces that does not show glacial striæ. Even tiny fragments but a fraction of an inch in diameter are found to be very generally marked.

When the softness of these shale fragments is considered and their association with numerous pebbles and cobbles and bowlders of hard sandstone, quartzite, etc, is borne in mind, it seems impossible to attribute their deposition to water. They are much too soft to endure even a limited amount of transportation by water without having their scorings obliterated. Much less could they stand water transportation along with hard materials, such as those with which they are associated, without having every trace of glacial striation effaced. If any added evidence is needed to prove their non-aqueous origin, that evidence is found in the shape of the fragments and in their association with materials of all grades of coarseness and fineness without trace of stratification.

The chemical and physical condition of the material near Little York is like that of the corresponding deposits near Oxford Furnace. The decomposable rocks have yielded to the influence of weathering and have lost their integrity. The clay is oxidized to the depth of the exposure and is wholly wanting in calcareous material. If this was ever present, it has been completely abstracted; in short, every feature of the material indicates age. On this ground alone it is impossible to think of it as having any genetic connection with the moraine. Furthermore, it is more than 100 feet higher than the moraine three miles or so northward. It is therefore physically impossible for it to have been derived therefrom by aqueous agencies. In the same vicinity bowlders like those of the till-like clay which has been identified up to elevations of 860 feet exist up to heights of 1,000 feet and more. In other words, the bowlders occur on the tops of the highest hills and ridges. Above 860 feet they were not seen in association with clay, but this is believed to be because of the absence of exposures. So far as surface indications afford criteria for judgment, there is every reason to believe that the bowldery clay is present on the highest lands in the vicinity, wherever they have not been subjected to a great degree of erosion.

Near Mount Bethel, a point five or six miles east of Oxford Furnace, the same type of bowldery clay, containing striated material, was seen at a height of about 960 feet. Like Oxford Furnace, this is but two or three miles from the moraine, but is several hundred feet above that part of the moraine which is nearest to it. As at Little York, the material is here wholly unstratified so far as exposed, and it occurs at the greatest elevations where exposures were found. Bowlders may be seen at the surface on the tops of the highest hills visited in the vicinity, fully 100 feet above the highest exposure of the bowldery clay seen. It is alto-

gether probable that the bowlders seen between 1,000 and 1,100 feet above tide are an index of bowlder-bearing clay existing here though not exposed.

Farther southward the same type of material occurs in the Pohatcong and Musconetcong valleys. If well data may be relied upon, there is as much as 70 feet of it in the valley near Washington, at an elevation of about 400 feet. From the localities cited it will be seen that the vertical range of the material is great within narrow geographic limits—fully 600 feet within six miles.

Still farther southward, near High Bridge, at an elevation about equal to that at Washington, or about 200 feet above the valley of the Raritan, close at hand, there is an exposure of about 30 feet of bowlder clay and gravel. As at Oxford Furnace, the material is here partially stratified, but a considerable proportion does not show any sign of orderly arrangement, and the bowlders are disposed in the clayey matrix after the fashion of true till. Bowlders five or six feet in diameter occur. One bowlder, whose greatest dimension is fully 7 feet, is glacially striated over nearly the whole of one face. As at Little York, so also here, one of the ingredients of the bowlder clay is shale in large and small fragments. Here also, as at Little York, it is difficult to find a piece of shale which retains the form it possessed when deposited which does not show ice scorings. In more than one instance bowlderets of shale were seen *in situ* showing glacial markings with great distinctness, but which were so far disintegrated as to make it impossible to remove them from their position without their crumbling to fragments. Among the fragments resulting from the disruption of shale bowlders pieces may be found which retain portions of the original surface, and upon these striæ may still be seen. The matrix in which the stony material is imbedded is locally of granite and crystalline schist origin—a sort of arkose. Its abundance may perhaps be due in part to the decomposition of the granitic material in the drift itself since its deposition.

High Bridge is about fourteen miles from the moraine at its nearest point. A few miles farther southwestward, near Pattenburg, the phenomena of High Bridge are repeated at a slightly greater elevation. But a single point of difference need be mentioned: the bowlder clay here rests on shale, the surface of which beneath the drift gives evidence of mechanical disturbance.

Similar occurrences of bowlder clay are known south of Pattenburg to a distance fully twenty miles south of the moraine. In all these places the bowldery clay is essentially constant in chemical and physical character, and whatever may be the explanation of its existence in one locality must be the explanation of it in all.

Nor are the phenomena above referred to restricted to the New Jersey side of the Delaware. South of South Bethlehem, in Pennsylvania, the same materials occur several hundred feet above the Lehigh valley. Finely glaciated bowlders imbedded in clay have been seen at more than one point south of the Lehigh at distances from the moraine comparable to those at which occur the Pattenburg and High Bridge deposits already referred to. In Pennsylvania, as in New Jersey, the material has a vertical range of several hundred feet.

Direct Evidence of Ice Work.—In the eastern part of New Jersey, near New Brunswick, some six miles from the moraine in direct line and at an elevation of 100 feet, there are some recently exposed sections which show a bowlder-bearing clay with rarely a glaciated bowlder resting on an irregular surface of Triassic shale. The irregularity is not of such a character as would be produced by erosion. It bears evidence rather of mechanical disturbance. In many places the stratification planes of the shale have been obscured by the crushing of the shale, but in other places, where the crushing effect has been less, the shale appears to have been pushed up into folds two to four feet high and with a width about equal to their height. In some cases these folds have been pushed over to one side, the bowlder clay wrapping around the inclined folds, lying beneath as well as above them. In other cases where stratification planes have been obliterated, or so nearly obliterated as to make their position indistinct, there are other phenomena exhibited scarcely less significant than those mentioned in determining the origin of the bowlder clay. There are places for considerable stretches where the material overlying the shale is essentially composed of red shale crushed to small fragments, or reduced to clay. This takes the place of the transported material which overlies the shale elsewhere. In the midst of such masses of broken shale, strictly local in origin, occasional bowlders of transported material occur, even down to the surface of the bedded shale. Exactly corresponding phenomena may be observed in many glaciated regions where the underlying rock is soft, or where a great amount of residuary material was accumulated on the surface prior to glaciation. It is quite comprehensible that such relations could be brought about by glacial action, but it is difficult to conceive how such results can be achieved by any other agency. At one other locality, fifteen miles southwest of New Brunswick, similar phenomena may be seen, though less strikingly developed.

Distribution of the Phenomena.—No determinations have yet been made as to the southern limit of this bowlder-bearing clay. The points in New Jersey and Pennsylvania mentioned above, however, are not the southernmost localities where glaciated material is known to occur. Striated bowlders have been found both by Mr. Charles E. Peet and the

writer at and near Monmouth Junction, nearly twenty miles from the moraine at its nearest point and fully forty miles south of the moraine on the same meridian. Glaciated material has also been found at Kingston, about half way between New Brunswick and Trenton. It has been found in Pennsylvania about three miles west of Trenton, near Falsingham. The similarity of the surface material of this locality to glacial drift (till) was first recognized by Professor Smock. Striated material has also been found at Bridgeport (opposite Norristown), Pennsylvania, by Mr. Peet and the writer, at least ten miles south of the parallel of Trenton. As at Falsingham, the striated material is here imbedded in clay of such a character that, were the locality known to have been covered by ice, its reference to till would be fully warranted. This locality is nearly or quite fifty miles south of the nearest point of the moraine. Striated material has also been found near Sunbury, Pennsylvania, between 25 and 30 miles south of the moraine in this longitude and at an elevation between 500 feet and 600 feet above the Susquehanna at that point. In all the localities last mentioned striation is relatively rare, but some of them have afforded bowlderets as beautifully striated as those of the Alpine glaciers of to-day.

Significance of the Observations.

General Bearing.—The foregoing statements give facts selected from a much larger body of data in the writer's possession concerning the distribution and nature and relations of extra-morainic surface formations. In the judgment of the writer these facts are sufficient to warrant the conclusion that glaciation extended further southward than the published moraine, both in New Jersey and Pennsylvania.

It is not to be understood that the writer would imply that land-ice has covered every region where glaciated material is found. The possibility of water transportation of glaciated material beyond the edge of land-ice is distinctly recognized, but it is not believed that water alone, or water bearing glacially derived bergs, could produce all the results which have been observed. Neither the physical and chemical condition of the material nor its geographic and vertical distribution are consistent with such an hypothesis.

From the character and relations of this extra-morainic drift, particularly from the degree of its oxidation, disintegration and erosion, it is confidently believed that it is to be regarded as the equivalent of the oldest glacial drift of the interior.

Number of Ice Invasions.—The conviction has been growing for some time in the mind of the writer that the commonly accepted division of

the ice period into two epochs may not be final. If this classification is to undergo modification, it is believed that the change will be in the direction of greater complexity. Data have been accumulating for some time past which would seem to be best explained on the basis of three ice epochs instead of two. This suggestion is less of an innovation than it may at first seem to be. President Chamberlin long since recognized two distinct episodes in the first glacial epoch, as classified by him, the two being separated by an interval of milder climate and ice retreat. The suggestion here made would simply emphasize this division already recognized. While President Chamberlin has hitherto regarded this interval of mild climate as marking a subordinate interruption of glaciation determining the division of the earlier ice epoch into episodes, Mr. McGee has regarded it as marking the greatest interruption of glaciation during the glacial period, determining the division of the ice period into two epochs. Mr. McGee's first glacial epoch would therefore correspond to the first glacial epoch of the classification here suggested, while his second glacial epoch would embrace the second and third as here proposed. On the other hand, President Chamberlin's first epoch embraces the first two, and his second the third epoch, if the ice period be divided into three epochs.*

Briefly characterized, the drift representing the ice advance of the first epoch has no marginal accumulation of the nature of frontal moraines. Its margin is attenuated. The drift representing the ice advance of the second epoch, according to the suggestion here made, is limited by morainal ridges, which are bordered and often covered by loess, loess-loam and silt deposits, which indicate slack drainage; while the drift of the third epoch is limited by stronger terminal moraines of more pronounced topography, in which valley trains and overwash plains of gravel take their origin. These valley trains of gravel often extend many miles down the valleys from the moraines, and demonstrate that the attitude of the land was such as to determine vigorous drainage. The degree of erosion, oxidation and disintegration of the drift of the several epochs is progressively less, from oldest to youngest. The significance of the silt and loess bordered moraines, as distinct from those bordered by gravel plains and trains in indicating continental attitudes, was long since pointed out by President Chamberlin, as was also the significance of the varying degrees of erosion, decomposition and disintegration of the drift. In briefly indicating, therefore, the broad divisions of the drift, corresponding to the three epochs suggested, the features noted are in no way

*Because of the importance attaching to his opinion on this question, I am glad to say that President Chamberlin is very hospitable to the suggestion here made of a tripartite division of the glacial period.

new, but were long since recognized by President Chamberlin and have been made use of by him and his assistants in field determinations.

Correlation of Deposits.—Apart from the inherent interest which attaches to the determination of the existence of a first glacial drift south of the moraine in New Jersey and Pennsylvania, this determination is likely to prove helpful in another direction.

The extra-morainic glacial drift in northern New Jersey and Pennsylvania affords a definite starting point for determining the relation of the glacial formations of the north to the coastal plain formations of the eastern and southeastern United States. It may not be out of place to add that the conclusion has already been tentatively reached that the "yellow gravel" formation of Dr. Cook is older than the extra-morainic drift. If this tentative conclusion shall prove to be correct, and if the drift be first glacial, then the "yellow gravel" must be preglacial, and therefore pre-Pleistocene.