EVIDENCES OF GLACIATION IN DEVONSHIRE.

BY R. HANSFORD WORTH, C.E.

(Read at Honiton, August, 1898.)

A. THE FORMS OF THE VALLEYS.

B. BOULDER CLAY.

FASHION appears to rule in geological as well as in other matters, the text-books being the authorities. With no sufficient reason, as it appears to the author, a very general opinion has arisen that the last glacial period was limited in action, and bounded as regards area by a line drawn eastward from the head of the Bristol Channel. No attempt, or at least no serious attempt, has ever been made to assign a reason for this southern limit of glaciation, and on inquiry it would appear that the matter is one of theory, formed in the absence of sufficient data. Of the reasons which may be assigned for the supposed absence of glacial action in Devonshire, two only, if seriously advanced, might be considered to be adequate. It must either be argued that the land of Devonshire was at the time of the last glacial period submerged, and hence freed from the action of the ice planes, or else that the climate obtaining in Devonshire during the glacial period differed so widely from that obtaining on the opposite coast of Wales, that glaciers, while possible in the one case, were rendered by climatic influence impossible in the other. So far as the author is aware neither of these arguments has been seriously put forward, but it is necessary none the less to deal shortly with them.

In the first place, had the county of Devonshire as a whole been submerged during the glacial period there must have been remaining evidence of drift ice having passed over the sea which covered it. Such evidence is practically non-existent, and where it could be found is restricted solely to the lower levels of the land. It will be seen, too, in the

course of this paper that there is evidence, and very full evidence, that the land constituting the present county of Devonshire oscillated in level contemporaneously and coincidently with the land now known as Wales, the physical conditions in both localities being identical. As to the question of climate, it is difficult or almost impossible to imagine that this argument could be seriously upheld. The actual distance between the land in Wales, which by common consent has been subject to glacial action, and the land in Devonshire is so slight as to afford no scope for a great change in temperature. Besides that, the relative elevations of the lower portions of Wales and of the surface of land in Devonshire are materially coincident, so that the question of temperature as dependent on elevation cannot be argued. If then there appear no sufficient reason for a difference of conditions on either side of the imaginary line before referred to, it might seem that the truest attempt to arrive at accurate conclusions would lie in the investigation of the present physical characteristics of Devonshire and its comparison with the conditions known to obtain in Wales.

For many years past the author has had exceptional advantages in studying the form assumed by the rock valleys in the south of Devonshire, and has not only obtained a fairly full knowledge of the present sub-aerial valleys, but has been enabled to accumulate a large amount of information as to the submerged valleys which form the estuaries of the southern rivers of Devonshire. In considering the facts from time to time brought before his notice, he has been driven to the conclusion that ice action has had great if not preponderating influence on the formation of Devonshire scenery.

It will be necessary to enter somewhat fully into the consideration of the physical differences between water erosion and ice erosion. Water in the course of its flow over the earth's surface undoubtedly exerts an erosive action, but this action directly depends, not on the primary force derived from the actual motion of the particles of water, but on the secondary motion of solid matters transported by the water flow. Thus it will be observed that at any place where even a considerable flow of water passes over a comparatively soft rock surface, the actual channel worn by the water itself is but slight, unless on its course the stream is fed with a sufficient amount of rock material in the form of sand, pebbles, and shingle. The power of a stream as an agent in excavation depends, first, on the volume of water; secondly,

on the gradient of the bed of the stream and the consequent velocity of flow; thirdly, on the quantity of detrital matter finding its way into the bed of the stream, and the relative hardness of this matter; so that the actual erosive power of water is compounded of its velocity and quantity, and consequent power of transporting solid particles, and the supply of solid particles for such transport. Another feature of water action is that however large the watershed, the actual flow of the stream is always confined to a relatively small section occupying the base of the valley only, beyond which, it is at the bottom of even this small section that the greatest cutting action is exerted, since solid matters transported by water occupy of necessity and in consequence of their gravity the lowest portion of the bed of the stream. Another feature of water action is that however great the initial erosive capacity of any stream, that power lessens from time to time, and continuously, as the stream itself, deepening its valley, reduces its own gradient, and consequently its velocity and its power of transporting solid matter.

In comparison with the motion of water the effect of glacier ice is very different. In the first place, ice in itself as a hard mineral substance is quite capable of wearing some rock surfaces by direct friction. In the second place, ice is to a great extent independent of velocity in its erosive action, inasmuch as however slowly it moves, it still transports rocks, boulders, and gravel with equally absolute certainty. Then again, ice, by reason of its weight, drags not only its own material, but transported detrital matter with greater pressure over the surface on which it moves. In the third place, there must be noted an even more important difference between the action of water and the action of ice. From a given watershed a glacier transporting a given quantity of water in the solid form will necessarily occupy a greater section in its valley than will a stream transporting an equal quantity of water in liquid form. Assuming, for instance—and the assumption is as well-founded as can be any general statement of varying figures—assuming that the average motion of a glacier is at the rate of one foot per day, and the average motion of a stream is at the rate of one foot per second, allowance being made in this latter case for retardation at points where the stream passes through pools, we obtain the fact that a stream which would require to occupy one foot in sectional area of a valley would in the solid form require to occupy 86,400 square feet of sectional area in the same valley. This in itself necessitates that the erosion,

instead of being confined to a narrow channel in the valley's base, must be distributed over a considerable width of base and a considerable height of the valley's sides. A slight correction of these figures is necessary in consequence of the fact that each glacier carries with it certain streams consequent on the melting of the ice; but against this correction we have to set by way of compensation the fact that whereas the stream conveys away the greater part of the rainfall each year in sudden and abnormal floods of short continuation, the glacier, fed by snow, distributes the flow from the catchment area almost equally over the whole period of any year.

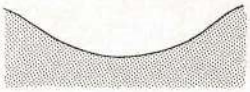
There remains another feature of contrast to be considered, and that is that while the solid matter conveyed by a stream finds its way at once to the bottom of the channel, the boulders and gravel conveyed by a glacier are almost equally distributed over the whole surface of contact between the glacier and its valley.

The result of these considerations, as a whole, leads us to the belief that we should always find a valley, the existence of which is due to water erosion, would have a section comparable to the letter V. The sides of such valley would in many cases be perpendicular, were it not that sub-aerial denudation breaks and frets away the rock-surfaces left by water erosion. But this action of sub-aerial denudation has its limits, since in the course of its continuance the rock ultimately arrives at its angle of rest, after which the denudation is mainly confined to action on the summit of the hill, and when once the surface is covered by soil, such denudation practically ceases; beyond which, in all cases in which the rock forming the valley is of fairly hard nature, the actual flow of the river erodes and creates new vertical surfaces more rapidly than sub-aerial denudation can break down and modify them. In the case of a valley eroded by a glacier the physical conditions are such that the cross-section of such valley tends to take the form of the letter U. More strictly speaking, such form is approximately parabolic. The base of a valley due to glacial action should be of considerable width, and should not present any definite channel cut beneath the general surface curve.

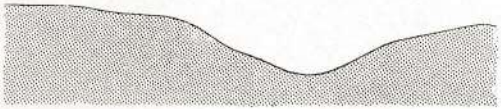
Without entering into debatable ground of the molecular action of ice in a glacier, the following facts may be taken as universally conceded. In the first place, that ice under pressure behaves as a plastic mass, as evidenced by the manner in which branch glaciers joining the main stream are frequently contracted to only a small proportion of their

original width. In the second place, that a glacier as a whole conforms in its flow to the laws of semi-fluid motion, as evidenced by the fact that the greatest velocity of flow along a straight portion of a glacier occurs at its centre and along a curved portion at a point nearer the concave side of its valley. A glacier exerts considerable active pressure on the sides of its valley in addition to the pressure of its weight on the base. Evidence of this may be found in the laminated structure of glacier ice. The whole of the conditions, therefore, of glacial erosion are in favour of action over a considerable depth of the valley; of active erosion exerted on its sides, and of the general contour formed of easy curves, without approach except in especial instances to the vertical. Ice being to some extent independent of gradient, will at places erode its valley in pits, followed by subsequent ridges or high places on the valley bed. It will also, where the rock is relatively soft, widen out and excavate a broad and shallow valley, followed at a point where the rock is relatively hard by a contraction of the glacier and the excavation of a narrow and deep channel. These theoretical considerations have the absolute assent of observed facts. Generally speaking, our sub-aerial valleys in Devonshire present no marked features of water erosion; broad swelling hills and broad undulating depressions are common. Four sections here figured have been purposely selected at narrow and steep portions of the valley of the Erme, Yealm, Plym, and Tavy. (Plate I.) The vertical scale is slightly over twice the horizontal, as otherwise the slopes would appear too insignificant. Even after thus doubling the inclination of the sides of the valleys, the sections yet appear to have fairly easy curves and graceful sweeps. It is not attempted to say that water erosion has not exercised a slight influence on the formation of these valleys, but the effect it has accomplished since their original excavation still leaves the slopes with the undulating form characteristic of ice action. Such sections might be indefinitely multiplied, and in nearly all cases with similar results. The exceptions which exist add weight to the evidence. Undoubted cases of water erosion occur in Devonshire, as for example at Lydford Gorge. Here the contrast is striking. The portion of the valley eroded by water shows absolutely precipitous sides, and at the bottom a channel, which just serves to accommodate the normal flow of the river. Here and there, in passing through the gorge, there may be observed points at which sub-aerial denudation, aided by the jointing of the

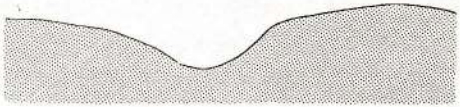
PLATE I.



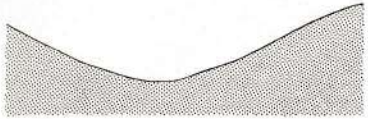
THE ERME AT ERMINGTON
DEPTH 260 FEET.



THE TAVY AT MILTON
DEPTH 350 FEET.



THE YEALM AT WINSOR.
1 MILE ABOVE YEALMBRIDGE.
DEPTH 300 FEET.



THE PLYM AT BICKLEIGH
DEPTH 400 FEET.

HORIZONTAL SCALE 2640 FEET TO 1 INCH
VERTICAL SCALE 1,000 FEET TO 1 INCH.

Plymouth Co
1798.

slate rock, has modified the original form left by the stream; but the extent to which this has occurred is by its comparative insignificance good evidence in itself of the necessity of looking to another cause than water erosion for the excavation of our Devonshire valleys.

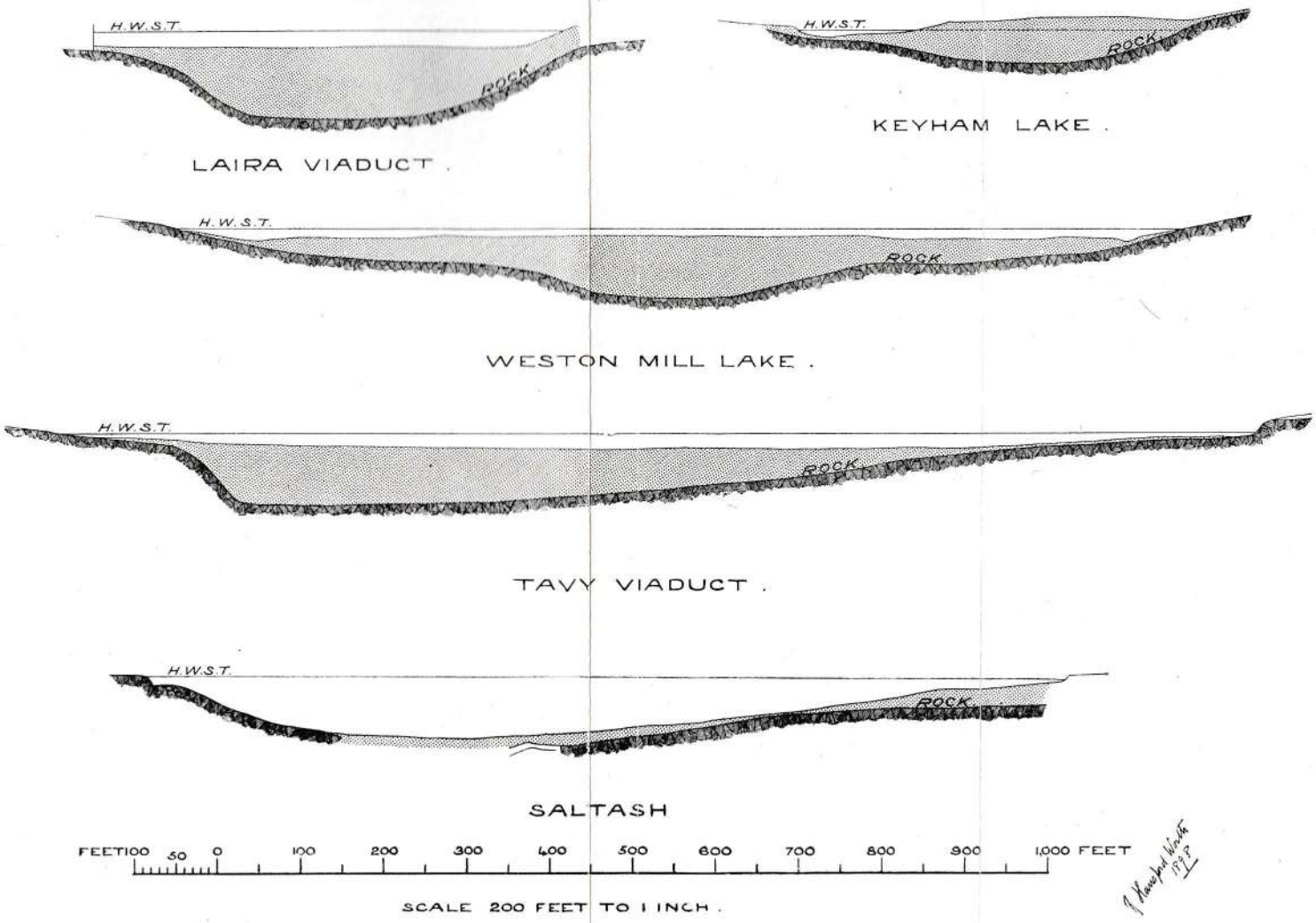
It is an interesting point in connection with the channel of the Lyd that vertically above the portion exhibiting undoubted water action may be seen a broad and shallow valley eroded by ice. Here then, we have a case in which the ice, having left a valley of considerable gradient, the subsequent flow of the stream has been enabled by its velocity and by the supply of granitic materials to so modify the original form as to create a practically uniform gradient from the moors to the point at which the glacial valley widens out near Lydford Waterfall. The whole concomitant action of sub-aerial denudation has entirely failed to materially modify the forms created by water erosion.

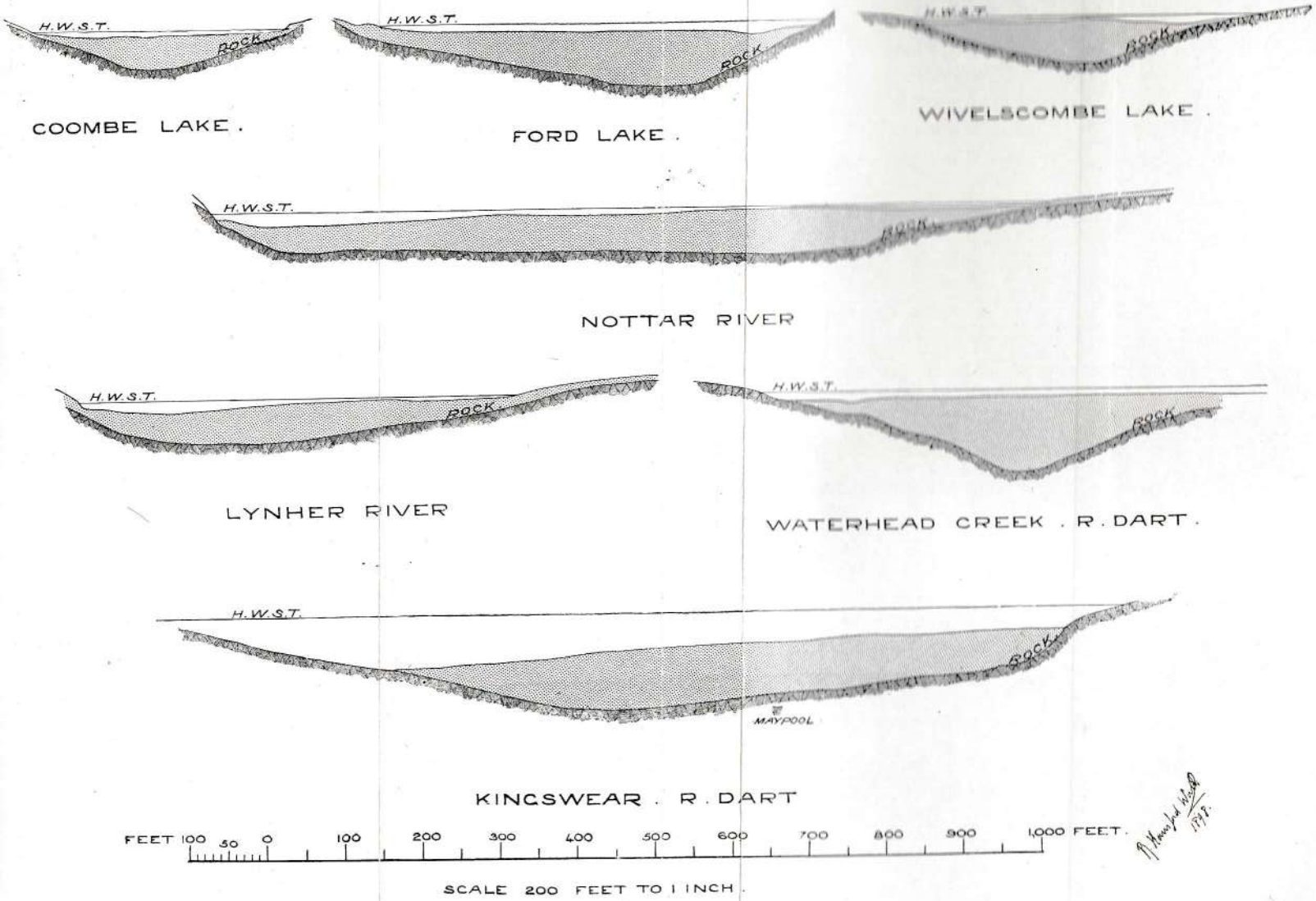
Now, were the greater number of our valleys to owe their formation to the erosive power of water, such examples as Lydford Gorge must be extremely common, whereas no similarly important case can be quoted, at least in the south of Devonshire. Although the beds of many streams, such as the Plym in Bickleigh Vale, give evidenee of genuine water erosion, this is absolutely insignificant as compared with the depth of the whole valley. It is a fair statement that since the time when the ice planes melted and receded the whole flow of our streams has but sufficed to slightly modify the mere base of the valleys formed by glacial action. Moreover, in many instances the rivers having failed to fill the channels left by the ice action, and finding the gradient too slight to enable them to exercise erosive action, have actually deposited material in the beds of the ancient valleys, filling and reconstructing in place of removing and destroying. If it be said that the present streams are degenerates from their predecessors, it must also be said that whatever the flow which passed down our valleys at and after the close of the last glacial period, it has never been sufficient to materially modify the characteristic forms due to glacial action. Thus from the sources whence, in consequence of subsequent disturbance, least direct evidence might be expected, proof in itself of great strength may be obtained of the general statement that ice has been the principal factor in shaping our hills and valleys. This fact (if fact it be), involves as a corollary that during the last glacial period the land surface must have been above sea level, and the

absence of erratic boulders, which would otherwise have been deposited by floating ice, supports this theory.

So far as to the evidence at present before the eye. The conduct however of various engineering works has placed at our disposal a mass of information, the great value of which is that it has reference to valleys now and long since submarine, and from their depth uninfluenced by subsequent erosion.

The depth of the valleys constituting our harbours and estuaries is hidden by the deposit of silt, which has filled the most of them to within comparatively a few feet of low water mark. At Plymouth, however, fairly full information as to the actual form and depth of the rock beds of the estuaries is available. The new railway bridge at Laira is founded on iron cylinders, each and all of which were sunk until they reached the limestone rock. The distance between the piers is uniformly 106 feet, and the first pier, at the west or Plymouth end, is founded upon rock at a height of three feet above low water spring tides. The next or second pier reaches a depth of 30 feet below low water, giving a fall at the rate of 1 in 3¼. The third pier reaches a depth of 80 feet below low water, giving a gradient of practically 1 in 2. The fourth pier reaches 87 feet 6 inches, and the fifth 86 feet 6 inches below low water spring tides, thus showing that for a breadth of 212 feet at the centre the channel of the rock is practically level at 87 feet below low water. Between the fifth and sixth piers there is a rise of 50 feet at the rate of 1 in 2, and the slope to the bottom from this point to the masonry abutment on the east bank is about 1 in 3¼, again corresponding with the other side. (Plate II.) This deep trough is not really the full extent of the matter we have to consider, for we must add the height of the adjoining cliffs in order to obtain the full excavation which has here been executed. From present appearances these cliffs must have risen to a height of at least 60 feet above low water spring tides. Recent borings in the silt of Cattewater Harbour confirm the result obtained at Laira Bridge. The depths reached are as great or greater, and the channel immediately below the bridge is very much wider than at the bridge itself, contracting again at Turnchapel Rock, and again expanding in the lower reaches of the harbour. The whole of this channel from Deadman's Bay to Laira Bridge is excavated in the Devonian limestone, and at no place is there traceable any distinctive depression which might have been occupied by water, or might be due to water action; further than which the gradients are such that the water would only have a


H.W.S.T.
ROCK
LAIRA VIADUCT.
H.W.S.T.
ROCK
KEYHAM LAKE.
H.W.S.T.
ROCK
WESTON MILL LAKE.
H.W.S.T.
ROCK
TAVY VIADUCT.
H.W.S.T.
ROCK
SALTASH
FEET 100 50 0 100 200 300 400 500 600 700 800 900 1,000 FEET
SCALE 200 FEET TO 1 INCH.


H.W.S.T.
ROCK
COOMBE LAKE.
H.W.S.T.
ROCK
FORD LAKE.
H.W.S.T.
ROCK
WIVELSCOMBE LAKE.
H.W.S.T.
ROCK
NOTTAR RIVER
H.W.S.T.
ROCK
LYNHER RIVER
H.W.S.T.
ROCK
WATERHEAD CREEK . R. DART.
H.W.S.T.
ROCK
MAYPOOL
KINGSWEAR . R. DART
FEET 100 50 0 100 200 300 400 500 600 700 800 900 1,000 FEET.
SCALE 200 FEET TO 1 INCH.

tendency to deposit material, and could have no tendency to erode.

Off the west pier at Sutton Pool, on the outside, a depth of 60 feet below low water failed to find rock, and this within 120 feet of the shore; while within the piers a depth of about 65 feet from low water to rock surface has been recorded. At the Great Western Docks there is a depth of 60 feet of silt on the line of the quay, forming the dam between the floating and the outer basin. In Firestone Bay, off Eastern King, soundings of 150 feet at low water are obtained. The bottom is rocky, and probably represents the actual rock bed of the harbour. Similarly, between Barnpool and Devil's Point, there is a pit of 132 feet of water. To the westward of the Rubble Bank there is yet another deep sounding of 102 feet. Through the kindness of the late Mr. Margary, the author was enabled to obtain full information as to the sections of all creeks crossed by the Cornwall Railway in the neighbourhood of Plymouth. Diagrams of these sections are attached to this paper. It is hardly necessary to deal at great length with these figures. It will be noticed that, as at Laira Bridge, so in these cases no definite channel for the normal flow of the stream has been found. The sections present at their centres, or at least at the centres of flow of the presumed glaciers, a considerable width, which in each case is practically level. The slopes leading to this central portion are in each case of comparatively easy gradient, and of fair curves. A few of the greatest depths obtained may possibly be quoted. Thus, at Weston Mill Lake (Plate II.), a section of which is singularly regular, the depth below low water is 66 feet; at Saltash Bridge (Plate II.) the depth is 75 feet; at Coombe Lake (Plate III.), near Saltash, the depth is 36 feet; at Ford Lake (Plate III.) 67 feet; at Wivelscombe Lake (Plate III.) 46 feet; the Notter River (Plate III.) occupies a channel the rocky bottom of which is 44 feet below low water, and the Lynher (Plate III.) occupies a similar channel lying 41 feet below low water. As regards a section taken at the new railway bridge of the London and South-Western Junction Railway at Tamerton, the deepest point reached was 15 feet 6 inches below low water, but this did not coincide with the deepest point of the channel. At the Tavy (Plate II.) the new viaduct on the same railway is founded on cylinders, and the information both as regards depth of rock surface and material overlying it is accordingly absolute. Starting at the Plymouth end, there are first seven spans of masonry

covering a length of 390 feet. In this length the rock surface falls from 5 feet to 24 feet below high water in a gradual incline. Then follow eight iron spans of 120 feet each. Where the masonry ends the depth of the rock below low water springs is 9 feet. In the first span of 120 feet this increases to 33 feet, or at the rate of 1 in 5; in the next to 43 feet, at the rate of 1 in 12; then to 52 feet, at the rate of 1 in 13½; then 62 feet, or 1 in 12; at the fifth pier 67 feet, at the rate of 1 in 24; at the sixth pier 68 feet; at the seventh pier 67 feet. The valley for a width of 240 feet is therefore practically level at a depth of 67 feet, which is below low water. Then follows a rapid rise to 3 feet, at the rate of 1 to 1¼. Two more spans of masonry complete the bridge, which obtains a total length of 1,440 feet. At the abutment on the north end the rock reaches the high water mark. It is interesting to note that the greatest depth of this valley and its steepest side are alike obtained near its concave shore, which in itself coincides absolutely with the known fact of glacial flow—that the highest velocity should also be obtained at this point in the same section.

Turning now to the longitudinal gradient of the Tamar estuary with a view of estimating whether it be possible that water action could have been responsible for the erosion of this valley, we find from the figures previously given that in the Hamoaze the depth of the centre rock bed below low water varies from at least 150 feet in Firestone Bay to 132 feet and over at Devil's Point, and 102 feet and over off the Rubble Bank. Between this last point and Saltash Bridge it is reduced to 75 feet, and at the Tavy Viaduct 68 feet is found. Absolute information is not available as to the depth midway between Tavy Viaduct and Saltash Bridge, but it is extremely probable that at this point the rock bed is deeper than either at Saltash or the Tavy. At any rate, on the known figures, the channel in the rock above Saltash is almost level for over two miles, the gradient being 1 in 1,508, and this at once disposes of the idea that any water action can have assisted in its erosion, and for three miles below Saltash the incline is only 1 in 515—evidence again that no stream of considerable velocity can have flowed over this portion of the valley since it assumed its present form. From the Rubble Bank to Firestone Bay it continues at the rate of 1 in 150. Coincident with this level portion before referred to as existing between Tavy and Saltash, is a great widening of the estuary into a lacustrine expanse, which is at its widest part five times the width of

the channel at Saltash Bridge. The contraction at Saltash may be readily explained by the presence of a number of dykes of intrusive igneous rock lying in a direction at right angles to the course of the valley. This feature of alternate contraction and expansion, which is so prominent in our estuaries, may also be traced in the sub-aerial valleys of Devonshire, and there are at present, notwithstanding the erosion due to water, which must be allowed to have had a restricted local influence, existing expanses of the valleys of Dartmoor having a greater width relative to their lower entrance than the Hamoaze has relative to Saltash, and of which the rocky beds are at the lower level at their widest points, the higher at the constrictions, which occur further down the courses of the streams. The fact that these valleys have been filled in by detrital matter from the rivers has hidden the undoubted existence of ancient lakes or tarns.

Although the author has restricted himself to the estuaries in the immediate neighbourhood of Plymouth, it may be stated that precisely similar conditions occur elsewhere in Devonshire and in Cornwall; notably the Dart, which coincides in all details, both of longitudinal gradient, of cross-section, and of alternate expansion and contraction, with the facts as set forth above. At one point a depth of 110 feet below low water has been recorded. I am enabled, by the kindness of Mr. T. Codrington, F.G.S., to give sections of Waterhead Creek and the Dart at Kingswear. (Plate III.) Mr. Codrington also kindly supplied me with a section of the Tamar at Saltash.

Summing up the evidence in favour of glacial action as derived from the present physical forms of our valleys, we have, in the first place, the absence of a defined channel of narrow area as compared with the whole depression, such as is invariably formed by water. In its place we find broad valleys, the lowest portion of which is the flattest, as compared with the narrow valleys, the lowest portion of which is the steepest. We have, too, the alternative expansion and contraction of these valleys coincident with the expansion and contraction of the level portion forming the lowest point thereof. The longitudinal gradients are such that the velocity obtained by even most considerable streams would not suffice for erosive action in such materials as our local rocks. Further than this, the streams, indeed, have only been enabled in many cases to fill in the beds of the valleys rather than conduct the excavations yet further. And again, as regards these longitudinal sections, at places, points further removed from the sea are more deeply excavated

than points nearer to the sea. All these considerations, in the author's opinion, are absolute evidence in favour of glacial action, and it is interesting to note that precisely the same features occur in the harbours and estuaries of Wales, where by universal consent glacial action has been the material cause of the present form of the land.

BOULDER CLAY.

Such evidence in itself as has been previously given may be thought to leave room for argument. When, however, correlated with the undoubted existence of glacial deposits, it assumes an importance which might not otherwise be attributed to it. Assuming that our valleys have been occupied by glaciers, some evidence of their existence in the form of transported material should be available, and remnants of this transported material may yet be found. For instance, at the mouth of our estuaries granitic pebbles are of constant occurrence, and in the case of the Yealm we have a river incapable of bringing down any granite boulders or pebbles to its estuary; yet on the beaches outside the estuary a notable proportion of granitic matter is found—a remnant, as the author suggests, of great quantities of material originally transported by the glacier which occupied the Yealm valley. And here it may be well to introduce a caution — that in the consideration of the submarine geology of the English Channel the possibility of boulders of considerable size having been transmitted direct from the high lands of Dartmoor, has in the past been largely overlooked. Erratic boulders should be common, although for the most part the glacier detritus is probably covered by subsequent marine deposits. Hence the presence of granitic or felsitic boulders on the Channel bed is not necessary evidence of an outlier of granitic rock. Any such boulders bearing a family likeness to our Dartmoor granites may very possibly have had their origin on Dartmoor itself. The case for glaciation, however, is not dependent on stray dredging or trawling in the Channel for evidence of genuine glacial detritus. At the Tavy Viaduct the rock surface was found covered to a depth of from 2 feet 6 inches to 4 feet by a bed of hard yellow clay associated with granite boulders. The deposits above this contained no granite boulders, nor even, so far as could be ascertained, granite pebbles. Evidently, therefore, the clay was deposited under conditions differing from those governing the subsequent infilling of the valley. This deposit had every characteristic of genuine

boulder clay. Similar deposits exist over a large area of the bed of the Cattewater, and are similarly covered by silt containing neither granitic pebbles nor boulders. And similar deposits are also reported by Mr. Codrington as existing at Coombe Lake and also on the Dart. Much more prominent, but hitherto entirely ignored, are the sub-aerial glacial deposits of the Tamar valley. At Rumleigh, on the Tamar, a bed of clay occurs resting on the rocky bed of the valley and containing a height of over twenty feet above present high water mark. The materials are unstratified, many are dissimilar to those now derivable from the river bed, considerable boulders of Gunnislake granite occur, and some at least of these give evidence by their form that they have not been water-borne. The characteristics are those of genuine glacial deposit, and the similarity between this clay and the boulder clays of the Mersey and of Wales are, the author is informed, very striking.

A very similar deposit occurs at the Weir Head on the Tamar. As conjoint evidence, it may be mentioned that the estuaries of the Welsh rivers exhibit similar patches and remnants of deposits of boulder clay.

Adding this evidence to the considerations previously advanced, the author is of opinion that a strong case in favour of glacial action in Devonshire must be admitted. Further considerations pointing to the same conclusion might be adduced, and such may possibly form the subject of another communication.

This paper would be incomplete without a reference to the terrestrial movements which have assisted in the causation of the present relations of land and sea. Passing over the period at which the land surfaces were sufficiently varied to enable the coral reefs to rise and grow in the shallow Devonian sea, and the period also at which the great mass of Dartmoor granite was elevated and intruded between the masses of earlier rock, we come to a much later time. There is evidence that the land level was once such that fluviatile deposits were formed on the crests of what are now the Hoe and Cattedown. In order that any stream might flow over these isolated headlands, we must assume that the surface of the land differed widely from its present contour. Between this stage and the next there exists a long interval, the details of which may not yet be filled in, although future discoveries may render this possible. And here the author would disclaim any intention of exactitude

in figures as to the extent of elevation attributed to the land surfaces. The heights and depths of such elevation as mentioned herein are merely minimum values which may have been exceeded, but must have been attained.

From the period of the raised beach on the Hoe the record is probably continuous. The Hoe raised beach is 40 feet above the present beach level. Hence the land lay 40 feet lower when it was formed. It largely consists of deposits derived by littoral drift from the shores of Cawsand Bay, or from rock surfaces now removed, but which then occupied the area of Cawsand Bay. In order that these materials might pass northward to the Hoe, it must necessarily be conceded that there existed a continuous shore-line, or, at least, that there was but an inconsiderable break. At present a chasm of about 170 feet in depth presents an impassable obstacle across which not even light pebbles, much less boulders weighing several hundredweight, could pass. This chasm cannot have existed when the raised beach of the Hoe was forming. Next follows a period of elevation during which the glaciers are engaged in eroding and sculpturing the land surfaces on the lines of the present estuaries. During this period the land rose to a height of at least 180 feet above its present levels. Before the close of the glacial period the land had again fallen to a level of 30 feet below the present, and the glacial clays, of which patches are still to be found in our valleys, were then deposited in the channels of our present estuaries. A series of beaches were formed round the coasts which constitute the majority of the present raised beaches. The glacial conditions slowly passed, and the land ultimately resumed an upward movement. Meantime, the deposits in the bone caves were probably formed. This upward movement extended to at least 80 feet above the present levels. Probably it was even more considerable. The deposits of boulder clay were slowly removed by water action, but the streams did not reach the level of the rock beds of the lower valleys. To this period of elevation we may attribute the forests which are now submerged. Following this came another period of depression, and the surface attained its present level. There is evidence that for a considerable time it has now been comparatively stable. The valleys from which the boulder clay had been almost entirely removed are now full of alluvial deposits. Periods of rest occurred during this last subsidence, as evidenced by successive layers of sand and oyster beds in the channel of the Laira.