

## II.—ON WATERSHEDS.

By GEORGE MAW, F.G.S., Etc.

IN connection with the discussion on the origin of hills and valleys, which has recently occupied the pages of the GEOLOGICAL MAGAZINE, I would submit a few observations on some phenomena, in evidence of the great power of subaërial denudation, which seem scarcely to have been noticed with the prominence they deserve.

I assume that the joint action of sea and river denudation is unquestioned, and that the main point under discussion is relative to which of these processes determined the final contour of the land.

What I wish particularly to notice is that the form of the whole land surface with some trifling exceptions (as lake basins, which appear to admit of special explanation) is merely a modification of the same principle of contour as the true river valley, exhibiting a system of watersheds by which almost every part of the land is connected with the sea by adjacent land on a graduated series of levels lower than itself.

Why is it that the surface is not irregularly undulating, exhibiting a fair proportion of its area in isolated depressions, surrounded on all sides by land more or less higher than itself? and why are not the valleys shut off into watersheds of defined area, terminating in isolated lakes instead of almost invariably finding common outlets at lower levels? In other words, why is it that you can approach the sea from any point of the earth's surface in an unbroken line of descent?

The various complications of upheaval must have left the surface with every variety of outline, including a fair proportion of isolated depressions; what then is the denuding power that has since stepped in and almost obliterated them, and replaced the chaos of form by the wonderfully uniform system of graduated levels that now, from mountain top to sea coast, envelopes the whole land surface?

Is not the difference between main channels, the recognised result of river action, and the graduated undulation of the entire surface one merely of degree? and is not the cause assignable to the contour of the principal valley also applicable to its tributaries, and to the whole graduated series of inequalities leading therefrom up to the very crest of the watershed?

The connection between this graduating system of contours and the principle upon which subaërial denudation ought to act, seems so natural that the *onus probandi* of any more probable cause should fairly lie with those who dispute the power of rain to effect the final sculpturing of the land's surface.

What can be more apposite than the apparent relation between the delicate gradation of levels from the river mouths *upwards* to the watershed boundaries, and the exactly proportionate concentration of water and consequent power of excavation *downwards* from the watershed lines to the river mouths.

Marine denudation can only have had two modes of operation,

either below the surface by the action of currents, or on the coast line.

In comparing the form of the sea bottom, and the land surface, it ought not to be overlooked that just as the land has been subject to marine denudation so the general form of the sea bottom may at one time have been influenced by subaerial action, and assimilated thereby to the form of the present dry land.

There is, however, one essential difference with regard to the much larger proportion of isolated depressions that occur in the ocean bed than on the land surface; as a rule the land consists of a graduated system of levels leading into each other as a connected series of watersheds, and the exceptions to it in the form of complete hollows are exceedingly rare; the sea bottom on the other hand is full of isolated depressions which would be left, on emergence, as unconnected pools and lakes, or isolated seas; this may be well observed on a miniature scale at low water on almost any shallow coast, and still better on a map of the sea bottom giving with sufficient detail the lines of equal depth. It seems impossible that such hollows should have been produced by any directly denuding force for which a line of approach seems essential.

Are not, therefore, these close sea valleys, surrounded on all sides by higher ground, invariably the result of accumulation? Similar depressions are not at all uncommon on the drift surfaces of Shropshire and Cheshire, and I believe that the close basins containing the meres and pools of these counties occur exclusively on old sea-bottom-surfaces of drift, or are the result of drift barriers closing up an ordinary watershed valley, and that a hollow of denudation of any extent, without an outlet at its lowest level, if it exists at all, is a phenomenon of the greatest rarity.

Lake basins, which seem to admit of special explanation, must, of course, be excepted; also, close valleys and depressions connected with swallow-holes, which are virtually complete watersheds in miniature.

Apart from the fact that the sea bottom as a rule is subject to accumulation rather than to any denuding process, on what possible theory can any system of marine currents excavate such a delicately graduating and ramifying system of levels and valleys as those forming the land's surface? In the first place, marine currents, though occasionally diverted by shallow barriers, are not as a rule coincident with the form of the bottom, and to refer the present shape of the ground to the action of former marine currents, you must assume that the greatest force was expended in producing the greatest depths, and this at once presents the difficulty of a system of currents diverging from the greatest depths and ramifying and exhausting themselves in every direction up what are now the river valleys to the lines of watershed; indeed, to be consistent, you must localise a branch of the supposed submarine current to fit every little depression of the ground that leads up from the watershed valleys.

Let us now look at the sea as a denuding agent on the coast line.

If marine action has been the exclusive cause of the moulding of

the present contour of the land, any zone of equal height on the land ought approximately to represent an ancient sea margin, and on the re-submergence of the land the coast ought to take up nearly its old position ; but lines of equal height on the land surface and neighbouring coast line have little or no relation to each other, and are generally not only different in their direction but also in the character of their outline ; and the same difference of character will be observable between a coast line produced by submergence without erosion, and one moulded by denudation. The prevailing tendency of the denuding sea-line is to be straight, and of a simply submerged coast, or of lines of equal height on the land, to be sinuous, bending round the ramifying valleys of the watershed system quite unlike the most sinuous coast cliff.

This is not so obvious to the eye in an actual view, because the sight cannot grasp at a glance a sufficient area, but if you follow it from the coast inland, and return to the sea at the same height at its other end, you will find that you have travelled in a very different direction, and a manifold greater distance than the line taken by the sea ; and when the land line is plotted down on paper it will exhibit a kind of structure very unlike that of the adjacent sea-board. In fact, the sea, in its erosive action on the coast, takes little or no account of the surface contour of the land ; it denudes back the high land in the shape of cliffs pretty nearly at the same rate as the lower ground of intersecting chines and combs, cutting indiscriminately across, and obliterating both hills and valleys, and working on a sort of jagged straight line singularly different to the winding line representing the lines of equal height on the land, which ought, according to the marine theory, to represent ancient coast lines of sea erosion. ;

Will the advocates of marine denudation, who assume that the sea excavated the glens and chines, intersecting the present sea cliffs (and many of them if prolonged would extend far below the present sea margin), explain why it is that the sea utterly ignores the old outline assumed for it, and follows one entirely different ? Instead of running up the valleys that are assumed to have been the result of its former action, and leaving the separating promontories untouched, as it must have originally done on the marine theory, how is it that it now breaks across both indiscriminately and removes with the same apparent ease a cliff 200 feet high and the low land that gently slopes down the glens under the sea ? The coast of the Isle of Wight, and the cliffs to the east of Hastings, well illustrate the form of outline on which coast erosion really works.

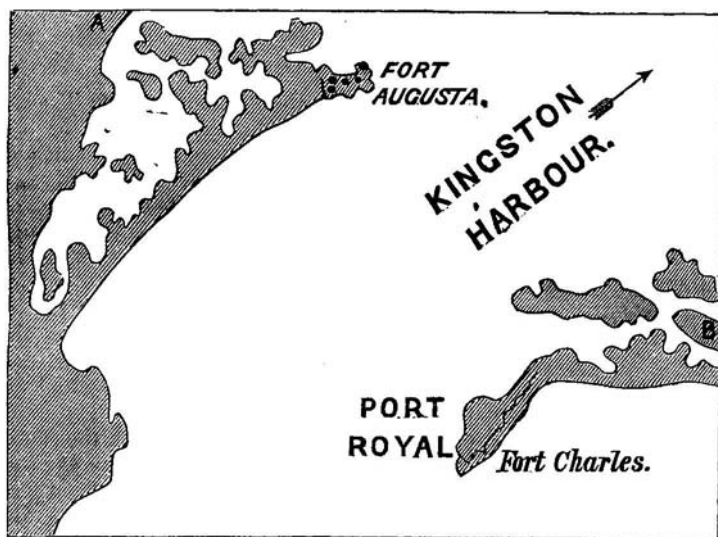
The subjoined engraving<sup>1</sup> of part of the coast at Port Royal, Jamaica, represents one of the very few authenticated cases of recent submergence, and affords a good example of the striking difference between a coast line produced by submergence following the form of the surface, and the ordinary coast line produced by marine erosion.

The coast at Port Royal, Jamaica, is known to have undergone a sudden subsidence in the year 1692, and has assumed an intricate outline notably distinct from any cliff-girt shore, and just the sort of

<sup>1</sup> Copied from the map appended to the Report of the Jamaica Commission.

form that would be expected from the sea running up among the gentle undulations of the watershed valleys. The sinuous line of the inner margin of the reef also forms a striking contrast to the comparatively straight margin of the exposed outer coast.

Another question that invites consideration is, that if marine denudation has determined the final contour of the land, how is it that erosion should have continued up the land-locked arms of the sea intersecting the submerged mountain chains, whilst the protecting flanks, exposed to the full force of the sea, remain? Unequal hardness and resistance will scarcely account for it, as the direction of the valley is not related to the structure of the rock. A map of the



A COAST LINE, THE RESULT OF SUBMERGENCE. PORT ROYAL, JAMAICA.

(Scale: 1 inch to a mile.)

The Coast connecting A to B takes a circuit of about 30 miles enclosing Kingston Harbour.

Snowdon district of the Italian Alps, or of a mountainous island like Jamaica, will, at a glance, exhibit the kind of outline with which the sea would surround a mountain chain at almost any zone of submergence; a large proportion of the water would be entirely land-locked, and the deep bays, where it must be assumed marine denudation continued with activity, would be protected from the active fury of the ocean.

No one will dispute that many parts of the land represent cliffs and coasts eroded by the sea; but these appear to be altogether subordinate to the watershed system, and do not, as a rule, harmonize with its outlines. The sea, in its trenchant action on the coast, may have done a greater work of erosion than subaërial denudation, but the two are inharmonious in their operations: the sea works

on the coast lines, and acts with indiscriminating destruction, breaking up, and more or less ruining, the old land contours; but subaërial and river action have always returned to the rescue, healing with delicate symmetry the disorder caused by marine denudation, remodelling and cleaning out the lost river channels, and reconnecting, into watershed and valley systems, the often submerged land surface.

### III.—ON THE STRUCTURE OF THE VALLEYS OF THE BLACKWATER AND THE CROUCH, AND OF THE EAST ESSEX GRAVEL, AND ON THE RELATION OF THIS GRAVEL TO THE DENUDATION OF THE WEALD.<sup>1</sup>

By SEARLES V. WOOD, Jun., F.G.S.

(With a Folding Map and Sections).

IN a paper in this MAGAZINE, upon the structure of the Thames Valley, I endeavoured to show that instead of being, as had been asserted, a valley of similar structure to those of the Somme and Seine, and containing deposits of nearly similar order and age, the valley in which the Thames gravel was deposited possessed no outlet to what is now the North Sea, being divided from it by a range of high gravelless country; and that, in lieu of such an outlet, the valley opened, in more than one part, over what is now the bare Chalk country forming the northern boundary of the Valley of the Weald. I also endeavoured to show that all the deposits of the Thames Valley, except the peat and marsh clay, belonged to several successive stages, marking the gradual denudation of the Boulder-clay, the lower Bagshot, the London Clay, and the subjacent Tertiaries, which had, at the end of the Glacial period, spread over the south-east of England in a complete order of succession: the sea into which this valley discharged occupying, what is now, the Chalk country of the Counties of Kent, Surrey, Sussex, and Hampshire, inclusive of the interval subsequently scooped out to form the Valley of the Weald: so that, not only was the latter valley newer than that of the Thames, and of the most recent of the Thames Valley deposits, except the peat and marsh clay, but that these deposits in themselves marked a long descent in time from that comparatively remote period of the Boulder-clay.

In a problem of this sort, the whole of the phenomena in the region affected by it should be in unison in order to render the evidence satisfactory, and the object of this paper is to show, as briefly as the multifarious nature of the evidence renders possible, that such is the case.

The East Essex gravel (which I so call from its principal development being in the east of Essex, although the southern extremity of it lies in Kent, fringing the Medway between the Nore and Rochester),

<sup>1</sup> This paper is intended as a continuation of that "On the Structure of the Thames Valley, and its contained Deposits," at pages 57 and 99, of Vol. III. of this Magazine, and the direction of sections 1, 3, 4, 5, and 6, given in that paper, have been shown by lines with corresponding numbers on the Map accompanying this paper.