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The morphology of the earth's surface

J. Geikie

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manent aspects of geography variously combined. The new agronomic maps of parts of France make the facts of the geological surveys available directly for agricultural purposes, and so form a step towards the ideal economic or commercial map.

My contention is that the future work of geographers must lie more in the discussion and co-ordination of different classes of phenomena as regards their distribution and interaction, than in the simple effort to produce a topographical map of high accuracy. The study of geography must thus increasingly demand a practical acquaintance with many sciences and modes of thought and expression, not for the purpose of carrying on researches in these sciences, but with the object of collecting their results and applying them to the elucidation of the Earth, viewed as the present expression of a definite evolution in which every part is subordinated to the production of a suitable home and sphere of influence for civilised man.

Viewed in this way, geography may be employed as a mental discipline in education in no whit inferior to other better-recognised gymnastics, and more likely than most to lead attentive students to results of practical value. Much remains to be done before existing data have been digested and utilised. That the geographical turn of mind is not necessarily material in its conception of the world it studies, may be readily proved by reference to the works of almost any modern poet. And no more beautiful instance could be afforded of its literary fruitfulness than Mr. R. L. Stevenson's description of how he built up his romance of *Treasure Island* from the basis of a map.¹

THE MORPHOLOGY OF THE EARTH'S SURFACE.

THE surface-features of the Earth and their origin is a subject which, ever since the days of Hutton and Playfair, has claimed the attention of geologists, although it is only within the last thirty or forty years that it has come prominently to the front. The irregularities of the land—mountains and valleys—were for a long time supposed to owe their origin directly to the action of the mysterious subterranean forces, and the great part played by running water in corroding and furrowing the surface of the land was hardly recognised until after the appearance of Hutton's famous *Theory of the Earth*, and Playfair's well-known *Illustrations*. Eventually it was realised by geologists generally that both hypogene and epigene agents have been concerned in the production of the Earth's surface-features. This is the view which presently prevails,

¹ The melancholy news of Mr. Stevenson's death reached Edinburgh only a few days after this lecture was delivered. Not alone in *Treasure Island*, but in almost all his stories and essays, geographical ideas find fit and graceful expression, and the world has lost a geographer while it mourns for a poet.

and which Professor Penck, in the masterly treatise named below,¹ sets forth with admirable lucidity. It is impossible, within the scope of a short article, to present anything like a complete analysis of this extensive and learned work. Needless to say, it is crowded with detail—the pages overflowing with references to the literature of the subject. It is, in short, a treasure-house of facts, and as such will be welcomed by geographers and geologists alike. Although the work contains references to the views of almost every writer who has discussed the character and origin of surface-features, it is far from being a mere cento of others' opinions. Throughout, the author deals with his subject in a thoroughly independent manner, and wins our attention not less by the admirable way in which his facts are grouped, than by the clearness with which he works out his conclusions.

Dealing first with the general morphology of the Earth, he treats in succession of the form and size of the globe, of geographical co-ordinates, of the methods of delineating and measuring the surface, and other mathematical-geographical questions. Thereafter the larger features of the earth are considered—the author concluding this preliminary section of his work with an instructive discussion of the question of the permanence of abyssal and continental areas.

Book II., which necessarily constitutes the large portion of the work, treats first of the general features of the land—the geological structure of the crust, and the origin of its manifold configuration. Starting from the point of view that the existing surface-features have resulted from the working of two sets of agents—one acting upon the surface from without, the other from within—the author proceeds to discuss the character and action of these exogenous and endogenous agents. This portion of Professor Penck's monograph may be said to traverse the same ground as Lyell's *Principles of Geology*. It is, in short, an elaborate discussion of what is known as Dynamical Geology. His treatment of the subject, however, is necessarily more advanced than Lyell's, and in many respects more detailed and comprehensive than the corresponding discussion in the larger textbooks of geology. The disintegration and transformation of rocks and rock-materials—the movements of masses, as in landslips, etc.—and the continuous degradation or wearing-away of the surface under the chemical and mechanical action of rain, frost, etc., are all brought vividly before us. Not less admirable is the account of the action of the wind in transporting disintegrated materials, and in wearing away the rock-surfaces over which such materials are swept. The action of running water and of ice next comes in for consideration, and we have an excellent account of the great work of erosion and accumulation performed by rivers and by glaciers. Under the head of "Modern Denudation," the author passes in review the various estimates of the rate at which the land-surface is being lowered. These estimates have been based on measurements of the amount of materials which are carried seaward by rivers. The annual discharge of material by any given river

¹ *Morphologie der Erdoberfläche*, von Dr. Albrecht Penck. 2 vols., pp. 471, 696. Stuttgart: J. Engelhorn, 1894.

having been ascertained, we know that its drainage-area has suffered just so much loss. As might have been expected, the rate of erosion thus measured varies considerably—some rivers carrying very much more sediment than others. Thus the amount of solid and dissolved material transported seaward annually by the rivers Elbe, Rhine, Meuse, Seine and Marne, and Thames, if we suppose it to have been taken equally from all parts of the land, indicates a general lowering of the surface of Middle Europe at the rate of 1 mètre in 32,900 years. The Rhone and the Danube, on the other hand, lower their drainage-areas to the same extent in 14,400 years. Taking the amount of material discharged every year by all the rivers of the globe as equal at least to 20 cubic-kilomètres, Penck estimates that this is equal to a layer 0.64 mm. in thickness removed from the regions of fluvial erosion (about one-fourth of the entire land-area). This would imply that the rivers lower the land at the rate of 1 mètre in 1440 years.

The first section of Book II. concludes with a discussion of the endogenous processes which have influenced the configuration of the land-surface. The movements of the crust, as in earthquakes—the dislocations, deformations, and foldings which that crust has experienced—are first described; and thereafter we have an account of the movements of the “magma,” as illustrated by modern volcanic action. This is followed by a discussion of the various hypotheses which have been held as to the condition of the Earth’s interior. The cooling of the globe and its consequences are next considered—the movements of the crust and the magma being the necessary results of that cooling. As the crust sinks down upon the cooling and contracting interior, it is crushed, dislocated, and folded—the compressed magma intruding itself into the fissured and dislocated masses, and here and there forcing its way to the surface in volcanic eruptions. The cooling of the globe is not equal throughout—there is more loss of Earth-heat in the oceanic basin than over the land. The permanence of the oceanic and continental areas is thus a necessary result of this unequal cooling. Hence the Earth’s crust naturally consists of two great regions:—(1.) The high-lying continental and low-lying abyssal regions, or relatively stable areas; and (2.) the zones of crust-folding, displacement, and volcanic action, or unstable areas. The stable regions are of enormous antiquity, and their origin is unknown—they were certainly in existence before the earliest fossiliferous strata came into existence. In the unstable zones, where the crust is subject to energetic movement, the adjacent sea-floor is now and again pushed up and added to the land, while, on the other hand, coastal areas are ever and anon carried down under the sea. Professor Penck concludes this portion of his work by a discussion of other suggested causes for crustal movements, such as the influence exerted by the increase and decrease of great ice-sheets, and by the removal of sedimentary materials from one region and their accumulation elsewhere.

The second section of Book II. contains an elaborate description of the various surface-features of the land, and an inquiry into their origin. It is impossible in a short notice to convey any adequate idea of the author’s treatment of this part of his subject. Beginning with the

simpler forms, he gives some account of the approximately level or gently undulating areas known as Plains—some of which owe their origin to erosion, while the larger number are simply the result of sedimentation. Next are described those rapidly undulating tracts—such as regions of sand-dunes—which, like most plains, have originated from transport and accumulation. Under the same head are included morainic regions, such as the *paysage morainique* of the Baltic ridge, and of many other formerly glaciated tracts, in which we find certain well-marked types of hills and hillocks of accumulation, such as end-moraines, drumlins, osar or eskers, and kames. Again, under the same category of “hills of accumulation” come the so-called mud-volcanos of such regions as Baku, and the “mud-lumps” of the deltas of large rivers like the Mississippi and the Indus. Next follows a long chapter on valleys, in which, after describing their various forms, their systems, and geographical distribution, he discusses their origin—coming to the general conclusion that valleys have been formed by the erosive action of running water. He points out, however, that the direction taken by streams and rivers has in many cases been determined by pre-existing depressions in the surface. Some rivers, for example, flow along the bottoms of structural hollows or synclinal troughs, as geologists term them, while others follow lines of dislocations. Again, volcanic action has occasionally produced great valley-like depressions, as in the Valle del Bove of *Ætna*. The irregular heaping-up of materials upon the land-surface has also originated valleys, as in the case of the hollows that separate adjacent lava-flows. Then we have long and often gully-like valleys produced by the falling-in of the roofs of underground channels; while other depressions of the surface have resulted from the erosive action of wind and of glaciers. Most of these hollows, however, differ from true river-valleys in their relatively short extent, their rectilinear direction, and more or less sporadic occurrence: they do not group themselves into manifold branching systems, and in many other respects offer strong contrasts to valleys which have been hollowed out by rivers. Reference may be made, in passing, to Professor Penck's discussion of the phenomenon of valley-within-valley. This is seen in many regions. In the valleys of the Eastern Alps, for example, three successive gravel-terraces are encountered—one within the other—indicating three successive levels at which the rivers were active in accumulating their alluvia. Each terrace is associated with moraines, and belongs, therefore, to a glacial epoch, during which the rivers swept forward a superabundance of material. The highest terrace rises upon an average about 250-300 feet above the present river; the surface of the middle terrace is about 100 feet below the surface of the highest, and about the same distance above the level of the lowest terrace. Each of the terraces rests upon solid rock, and it is obvious, therefore, that the several epochs of gravel-accumulation have been separated by epochs of active valley-erosion. In this case the phenomenon of valley-within-valley is clearly the result of climatic changes. The highest terrace indicates the action of flooded rivers escaping from great glaciers. The glaciers then disappeared, or shrank into comparative insignificance, and an epoch of active valley-erosion

succeeded—the rivers cutting their way down for a hundred feet or more into the solid rocks. Next came a return to glacial conditions, and the lowered valley-bottom was again deeply covered with gravels. The glaciers once more retired, and the rivers as before deepened their channels, working down through the gravels, and excavating the underlying solid rocks. Thereafter came a third advance of the glaciers, and a new series of gravels was deposited at a lower level than the preceding accumulation. Lastly, this third glacial epoch passed away, and the rivers again trenched the fluvio-glacial gravels, the upper surface of which is now much above the reach of the greatest floods. It is needless to say, however, that the phenomenon of valley-within-valley is sometimes the result of other than climatic changes. Movements of the Earth's crust have again and again produced similar changes. Sometimes by such movements the valley-gradients have been increased, at other times they have been diminished, and the rate of river-erosion has thus been from time to time modified. Not infrequently, indeed, valley-erosion has been interrupted for longer or shorter periods by the depression of the land under the sea, and renewed upon its re-elevation.

Having discussed the origin of the valleys, Professor Penck goes on to describe the various aspects presented by valleys and the lands they traverse. He then passes in review the several characteristic features of plateaus and plains, and of mountain-regions, such as those of Middle Germany and the loftier heights of the Alps. In each case he points out in detail the relation that obtains between the internal geological structure and the external configuration of the ground, and shows how the ultimate form of the surface, as worked out by denudation, has been determined by the character of the rocks, and the mode in which these are arranged. He then passes on to consider the character and origin of basins or depressions which, save in some desiccated regions, are usually occupied by lakes and inland seas. The author's classification of these basins is partly geographical, partly geological. He describes them under the following heads:—(1.) Basins of dry regions; (2.) Basins of glaciated regions; (3.) Basins occurring in regions of readily soluble rocks; (4.) Basins in alluvial plains; (5.) Basins of volcanic regions; (6.) Basins of mountain regions. The basins of dry regions, such as those occupied by the Dead Sea, the Caspian, Issyk-Kul, the Great Salt Lake, etc., and many dried-up depressions in these and similar more or less desiccated tracts, are doubtless for the most part the result of crustal deformation. Those areas which have formerly been subjected to glaciation are, *par excellence*, the lake-regions of the earth. Many of the larger lakes in those areas are of great extent and depth, such as Ladoga, Onega, Wener, Mälär, etc., in Europe, and Superior, Huron, Michigan, etc., in North America—the bottoms of all the lakes named being under the level of the sea. There can be little doubt that these and similar extensive lakes in the same regions occupy depressions which, however modified they may have been by glacial action, are yet the result of crustal deformation. By far the larger number of the lakes in North America, Northern Europe, Patagonia, and New Zealand, however, are more or less directly due to glacial erosion and accumulation. Their geographical

distribution alone is suggestive of such an origin—for they are restricted to regions in which glacial phenomena are developed. Thus, in Europe, outside of the glaciated tracts, lakes are of exceptional occurrence; and these are confined to districts where soluble rocks abound, to volcanic tracts, and to steppe lands, like those of Hungary. The same holds true for North America. Nearly all the larger and smaller lakes of that vast region lie within the glaciated areas. So also in Patagonia, New Zealand, and Tasmania, lakes and glacial phenomena are closely associated. In each formerly glaciated area we recognise two more or less well-defined regions—a central tract of glacial erosion, and a peripheral tract of glacial accumulation. The latter forms the well-marked *paysage morainique*—characterised by its hummocky surface—and presents a strong contrast to the glacially eroded region which it bounds. Here naked rock comes again and again to the surface—showing the characteristic mammillated configuration known to geologists as *roches moutonnées*. Here also we meet with the eskers and drumlins, and occasional end-moraines, which have already been referred to. In the true *paysage morainique* the lakes, often extremely abundant, are as a rule of relatively small extent and depth. Many occupy hollows which are obviously due to the irregular heaping-up of morainic materials; others appear to have been excavated by “glacier-mills” (i.e. by water descending to the bottom of the old ice-sheets), while yet others may have resulted from the subsequent melting of masses of “dead ice,” formerly buried under glacial accumulations. In the central region of glacial erosion the lakes frequently lie in true rock-basins; at other times they rest partly upon rock, partly upon glacial deposits, the hollows they occupy presenting now and again the appearance of having been dammed up by morainic accumulations. The rock-basins are not restricted to any particular kind of rock—occurring in granite, gneiss, greywacké, etc., as well as in limestone. Not infrequently rock-basins occur in regions of relatively soft rocks, surrounded by higher ground composed of more resistant materials. In Sweden, for example, certain lakes fill hollows in the Archæan rocks, which there is evidence to show were formerly occupied by Silurian strata. Others, again, are supposed to lie in basins which have been formed by the removal of more or less incoherent weathered rock-stuff. In flat lands which have been traversed by a thick ice-sheet, most of the basins which extend in the direction of glacial movement have been eroded by the ice. They, and the long parallel ice-worn ridges which separate them, recall the appearances presented by the wind-modelled surface of a region of sand-dunes—where long ridges and banks, with intervening hollows, extend in one and the same direction. Here and there, however, where the ice-current has been stemmed by abrupt hills and crags, hollows have been eroded in front of such obstructions, and hence we have a series of lakes occupying “deflection-basins,” which extend more or less at right angles to the general direction of glaciation.

The next class of basins described by the author are those which occur in regions where permeable and readily soluble rocks abound. While the basins of desiccated and of formerly glaciated tracts have a wide regional development, those of the class now under review are

naturally restricted to areas where calcareous rocks, gypsum, or rock-salt occur in more or less abundance. A particular account of the various forms assumed by the depressions in such regions is given, and their origin is described; and thereafter the author takes up the subject of "alluvial lakes." A large number of these are more or less temporary. They come into existence when the rivers are in flood, and by-and-by disappear when flood-time is over. Others, again, occupy the deserted loops or bends of rivers, and may have a more or less protracted existence. The basins and lakes of volcanic regions next come in for notice. Many of these occupy old craters; some of the lakes, on the other hand, owe their origin to the damming-up of hollows by lava-streams, while not a few may be due to local depression of the surface, or to unequal deposition of volcanic ejectamenta. The last series of basins considered by Professor Penck are those which occur in mountain-regions. Many of these, generally of limited extent, appear near water-partings. Some of them are due to the unequal heaping-up and distribution of loose materials by the action of the wind, while others occupy slight depressions caused by the removal of rocks in solution. Those which occur in passes are often caused by the accumulation of *débris* derived from the adjacent mountain-slopes. In other cases the dams which retain the water are of morainic origin; while yet other "pass-lakes" lie in rock-basins which have been ground out by ice. On the slopes of the mountains, lakelets formed behind dams of morainic origin are of not infrequent occurrence, but owing to the porous nature of the dams these are generally soon drained away. Again, rock-falls and great landslips have often served as dams, behind which lakes have formed. But the most commonly occurring lakes on mountain-slopes are those which occupy the bottoms of cirques or corries. A corrie is a niche-like recess on the flank of a mountain, usually at a considerable elevation above the bottom of the adjacent valley. Several such corries often occur on the same mountain-slope, rising one above the other. Not infrequently a lake lies in the bottom of a corrie—sometimes occupying a rock-basin, at other times apparently dammed-up by a wall of rock-*débris*. The presence of ice-worn and striated rock-surfaces and moraines shows that the corries are the beds of former small glaciers, which descended no great distance below the *névé* fields of past times. Hence we find that the cirques of any given region occur in determinate zones. Thus in the mountains of Middle Germany cirques are restricted to a zone ranging between 950 and 1050 mètres above the sea. As "secondary" or "summit glaciers" of the kind referred to seldom reach much below the *névé*, the zone of the cirques enables us to determine approximately the former level reached by the *névé* at a certain stage of the glacial period.

It is in the valleys of a mountain region, however, where the largest basins are encountered. These, like all the other basins of such regions, owe their origin partly to causes now in action, and partly to former glacial conditions. In not a few cases lakes have been formed in main valleys by the action of lateral streams carrying down immense quantities of sediment, and so locally raising the bed of the main valleys. Again, a river by raising its own bed sometimes succeeds in damming a lateral

valley. But although lakes of such a kind are well known, yet it is to the action of former glaciation that most of the basins of mountain regions are due. The valleys of all glaciated mountain-tracts have a characteristic physiognomy. They all head in vast valley-cirques; their fall is irregularly step-like; frequently basins extend along the valley-bottom, or, if these be wanting, there is yet evidence of their former existence, unless the whole valley-bottom has been subsequently filled to some depth with later accumulations. The basin highest up such a valley not infrequently occupies the bottom of the cirque-like head; the lowest basin lies near the end of the old glacier—sometimes within the mountains, at other times at their foot, or extending outside of the mountains altogether. The structure of the valley-basins of formerly glaciated mountains shows that some of these are moraine-dammed, while others are excavated in rock. But between these two extreme types occur many which are partly rock-basins and partly dammed-up by morainic *débris* and fluvial accumulations. In other words, were all the superficial deposits in such mountain-valleys as those of the Alps to be removed, several of the great lakes would be considerably reduced in depth and extent. The level of Lake Constance, for example, might fall about 40 mètres, and the lake would then lose a third of its area. Again, it is supposed that Lake Como is partly dammed-up by the great river accumulations which form the plains of the Po. These are not less than 150 mètres in thickness, and the basin of Lake Como is 400 mètres in depth. Could the old river alluvia be removed, therefore, that lake might be reduced to a depth of 250 mètres, with hardly half of its present area. All the great lakes of the Alps are of recent age—none of them dating beyond Pleistocene times. It is noteworthy, also, that these basins bear no relation to the internal structure of the mountains. They extend across different formations, traversing “saddle-backs” and “synclines” alike; the rock-foldings along the northern borders of the Swiss Alps nowhere influence them: they are younger than the building of the mountains, younger even than the later movements which have affected the low ground at the foot of the Alps. Thus, according to Professor Heim, a depressed anticline, 300 to 400 mètres in height, trends along the foot of the Alps in the region occupied by Lakes Constance and Zurich. This “swelling” affects the older Pleistocene deposits, and is consequently of quite a recent age; and if the basins of these great Alpine lakes had been caused by such deformations, we should have expected to find them lying in the mountain-valleys behind the depressed anticline referred to. But both lakes (*Constance* and *Zurich*) extend right across it, the deepest part of the latter being not far from the back of the anticline itself. That the formation of valley-lakes is quite independent of mountain structure is further shown by their geographical distribution. They are present in the Alps, but in the similarly built mountains of the Himalaya they are wanting, while they abound in the highly eroded regions of Northern Europe, where all the elevations are mountains of denudation. Everywhere they are inseparably associated with evidences of glaciation. But, as already remarked, all the lake-basins of a glaciated mountain-tract do not necessarily lie in rock-basins.

Not a few lakes are dammed-up by morainic and other superficial accumulations, or by great rock-falls and landslips. As regards the general distribution of mountain-lakes, one finds that while cirque-lakes and high-lying valley-lakes are met with everywhere in the loftier mountains of the globe, lower-lying valley-lakes, like those of Switzerland and North Italy, are much less widely distributed. They occur only in regions where valley-glaciers have formerly descended to the low grounds. They are wanting in the mountains of the warmer zones, as in the Himalaya, the Andes of Peru, of Ecuador, and Colombia; in temperate regions, as in the Alps of Europe and New Zealand, they are well developed; while in colder zones, as in Scandinavia, they extend far beyond the mountains, and are scattered over the adjacent low-lying tracts.

Having discussed the character and origin of basins, whether occupied by water or not, Professor Penck proceeds to consider the subject of mountains. According to the character of their declivities, mountains may be grouped as follows:—(a) Escarpment mountains, built up of strata inclined in some general direction; (b) anticlinal mountains, formed of strata dipping in opposite directions from a central axis; (c) fault mountains, great blocks bounded by dislocations; (d) flexure mountains, built up of highly folded and flexed strata; and (e) volcanic mountains. In the formation of mountains endogenous and exogenous agents work together. Movements of the crust and the magma produce the block out of which the agents of erosion subsequently shape the mountain. Further, as we learn from the geological structure of many regions, denudation can in time reduce mountains to a plain. Hence we may infer that all existing mountains are either relatively young formations, or regions of permanent crustal movement. A long and interesting description of the various classes of mountains and their phenomena is followed by an account of the depressed regions of the land. These, for the most part, are low-lying lands; but this is not always the case, for many sunken or depressed areas are met with in elevated regions. Very varied are the surface-features presented by depressed lands. Sometimes they are plains, or they may be hilly and undulating; often they are traversed by a well-marked system of river-valleys, and not infrequently they are basin-shaped. In general, however, they show a flat surface, and this is the rule with those that occur in low-lying districts. The depressions at high elevations, on the other hand, are often intersected by deep valleys. Not infrequently sunken areas are partly or wholly occupied by lakes or inland seas, while now and again they appear as gulfs of the ocean. Several types are recognised, each characterised by a special geological structure. Thus a succession of escarpments dipping, say, in an easterly direction are usually separated the one from the other by long depressions extending north and south. So, again, just as we have high grounds coinciding with broad and flattened swellings of the crust, so we find depressed areas which are obviously geo-synclinal troughs. Once more, some mountains, as we have learned, are bounded by great dislocations. They are mountains because the surrounding tracts have sunk down, and such sunken tracts form another well-marked type of surface depression. Not less well-defined are the flexure depressions which are associated

with flexure mountains. As a rule, these are best developed at the foot of the mountains. Thus we have the depressed region of the Po at the base of the Alps and the Apennines, and the Swiss plain between the Alps and the Jura. Yet another type of depressed land is found lying between volcanic chains, a good example being the lake-dappled region of the highlands of Mexico.

Professor Penck concludes Book II. with an account of caves and the mode of their formation. Book III. he devotes to the consideration of the sea. After some remarks on the general morphology of the oceanic basin, and the contrasts which it presents to the surface-features of the land, the author gives a comprehensive account of modern marine action. The work performed by waves, tides, and ocean currents is discussed in detail, and the formation of river-bars, deltas, coral reefs, and mangrove swamps is described. Movements of the coast-line next come in for treatment. Such changes may be due either to movements of the coast or to actual oscillation of the sea-level, or to both combined. Deformation of the crust is not restricted to the dry land, and the sea-level may be affected either by changes in the capacity of the oceanic basin, or in the volume of water it contains, or by deformation of the surface of the sea itself. Crustal movements may increase or diminish the extent of the oceanic basin, and thus cause the sea-level either to fall or to rise relatively to the land. Again, as the sea is the great receptacle for the waste materials of the land, it is obvious that sedimentation alone must tend to lessen its depth. If, in 12,400 years, the land-surface of the globe were lowered by denudation to the extent of 1 mètre, the sea-level, in consequence of sedimentation, would rise at the rate of 1 mètre in 32,200 years. The volume of water is likewise liable to change. During the glacial period, areas of 20,721,000 square kilomètres in North America, and of 97,138,000 square kilomètres in Europe, were covered with ice. If the mean thickness of the ice were no more than 1 kilomètre, this would imply the removal of at least 25,630,000 cubic kilomètres of water from the sea, and the lowering of the surface by 71 mètres. If the Antarctic regions were contemporaneously glaciated on a similar scale, the sea-level would of course be still further lowered. Nor can we quite ignore the influence which the filling or emptying of inland seas and depressions would have on the general oceanic level. Were all the waters of inland seas and lakes to be restored to the ocean, the sea-level would be raised by 8 mètres. On the other hand, were all the desiccated hollows and depressions of the land-surface to be filled with water, the sea-level would probably sink to a similar extent. The filling of the Aralo-Caspian depression alone would reduce the oceanic level by 4 cm. Now, the glacial period was characterised not only by great ice-sheets and glaciers, but by the presence of numerous lakes and inland seas—many of the broad depressions of the land which are now either partly or wholly dry were then occupied by water, and the removal of this water alone from the sea must have lowered the oceanic level by 8 mètres. Add this to the depression caused by the extensive accumulation upon the land of snow and ice, and we have a lowering of the general oceanic level in glacial times of 79 mètres. But changes in the volume of the

oceanic waters may be caused indirectly by crustal movements. If, for example, a geo-anticlinal were formed across the Strait of Gibraltar so as to convert the Mediterranean into a great lake, the surface of this lake would gradually fall. The lowering of its surface by evaporation to the extent of 500 mètres would raise that of the ocean by about 3·5 mètres. Again, as the surface of the sea is perpendicular to the earth's centre of gravity, it follows that any changes in the distribution of mass within the crust—all crustal and mass movements—must affect the sea-level, and thus bring about changes of the coast-lines. The piling-up of great water-masses in the form of ice upon the land must likewise cause deformation of the sea-level. Thus an ice-sheet tends to produce around it deflection of the plumb-line, and a rising of the sea-level; but any rise of level thus brought about is masked by the relatively greater depression caused by the withdrawal from the sea of the water locked up in the ice-sheet itself. It is conceivable also that changes of sea-level would be induced by changes in the rate of rotation, and in the position of the axis of rotation. Such changes would, of course, affect the lithosphere as well as the ocean; but the latter, owing to its greater mobility, would be more readily influenced.

Although we may look upon the surface of the sea as preserving upon the whole one and the same level, yet, as is well known, this is not quite true. Wind heaps up the water in bays and estuaries, and the surface also rises and falls in obedience to changes in the atmospheric pressure. Again, all sea-water has not the same specific gravity—the less saline areas have a higher level than those which are salter.

While it must be admitted that changes in the position of coast-lines have sometimes resulted from actual changes of the oceanic level, it is no less certain that crustal changes within the land areas likewise produce similar results. Close observation of the Scandinavian coast-lines has shown that a belt of land extending from the Skager Rak to the Gulf of Bothnia is slowly rising in the form of what geologists term a geo-anticlinal. Again, coastal changes now and again result from the gradual consolidation of alluvial and other loose accumulations. Thus, the low-lying lands of Holland, drained by dykes and protected by embankments, have gradually subsided, so that the surface of the land has been reduced below the sea-level. In other low-lying alluvial coast-lands, the gradual consolidation of superficial deposits brought about by underground drainage leads to slipping and subsidence, and permanent changes of the coast-line follow. To the coastal changes caused by movements of the sea-level itself or by movements of the land, we must of course add the modifications induced by the action of the waves and breakers.

Having considered the several causes of coastal changes, Professor Penck next devotes a chapter to the description of sea-coasts. The character of a coast-line necessarily varies according as the land slopes gently or abruptly into the sea. Some coasts show a smooth or even outline, some are broken by numerous indentations, while others are interrupted by great gulfs. Each of these types is separately considered. Smooth coast-lines are sometimes low-lying, sometimes flanked by more or less precipitous cliffs. Indented coast-lines are characteristically

represented by the fiord-coasts of northern regions, and it is to such regions that the famous "Strandlinien" and coast-terraces are restricted. A true fiord is always deeper than the sea immediately beyond its mouth. The north-west coast of Spain is penetrated by deep indentations, such as the Ria de Vigo; and similar narrow gulfs occur in many other regions, as in Cornwall, Brittany, and south-west Ireland. These, however, differ from true fiords in deepening gradually outwards to the external ocean—they contain no basins. In other cases the indentations are of less extent; such are the small semi-circular bays which interrupt the coasts of Malta and the Balearic Islands (*Cala* coasts), and the relatively broad and short indentations which are presented by the coasts of the Red Sea. All these indentations are the result of depression of the land: the fiords and *rias* are submerged valleys, while the "*cala*"-coasts of Malta, etc., and the "*scherm*"-coasts of the Red Sea, indicate sunken tracts in regions where the valleys are of little importance. The basins included in true fiords are due partly to glacial erosion and partly to glacial accumulation. The strongly lobate coasts are typically represented in the Greek Archipelago, where deep gulfs penetrate the land, and are separated by bold and lofty peninsulas. Now and again such indentations meet, and form straits. As a general rule, coast-lines of this character are the result of crustal movements. Coral-reef coast-lines are next discussed in considerable detail; and thereafter the author treats of Straits and their origin, and concludes his account of coast-lines by a description of the several kinds of coastal-lakes or lagoons. The work concludes with an interesting description of the sea-bottom, and an excellent account of continental and oceanic islands.

In this rapid outline of Professor Penck's book we have indicated very imperfectly its general scope, but we cannot do justice to the learning which its pages display. It is the most comprehensive treatise on the subject in any language, and will doubtless take rank as a standard work. The style is clear and straightforward, and this makes pleasant reading. We congratulate the author upon the successful completion of his laborious design, and cordially commend his work to the careful attention of all who are interested in geographical and geological studies.

J. GEIKIE.

THE HIGHEST VILLAGE OF THE CAUCASUS AND THE SHAKH-DAGH.¹

IN the summer of 1892 M. Pastukhoff made a journey in Daghestan to execute topographical surveys. On the 28th August, with six troopers, he left his camp, situated on the flank of the Loss range at a height of 7742 feet, $3\frac{1}{2}$ miles to the north-west of the village of Diibuk, his chief object being to visit two of the highest villages of the Caucasus, Chirakh and Kurush, and to ascend the summit of the Shakh-dagh

¹ From an article by M. Pastukhoff in the *Zapiski* of the Caucasian Branch of the Imperial Russian Geographical Society, Book xvi.