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Mountains

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At any rate, until, say, ten or fifteen years we find that the natives of the Uganda Protectorate are hopeless, that they will do absolutely nothing to develop, under our direction and for their profit, the resources of the country in animal, vegetable, and mineral wealth—until then I consider we ought to be most careful not to repeat a policy which has been shown to be unfortunate in its results in the Congo Free State and in certain French colonies. Commerce ought to be absolutely free and unrestricted in the Uganda Protectorate. If the native profits by developing the resources of his country, the administration of the Protectorate will profit also, for the native will have money with which to pay his hut and gun taxes, the export duty on certain goods, or the import duty on others. The European merchant will find his gain in the cheapness of native labour, and consequently the low price of the native products which will be tendered to him for purchase. But do not let us—at any rate until we have tried other expedients and failed—hand over large districts as exclusive concessions to this or that company for rubber, timber, ivory, or coffee. Special arrangements in regard to mining may possibly have to be made owing to the utter inability of the native to develop that particular source of wealth. At the present time any European or foreigner (or, for the matter of that, any native) can purchase from the Crown an estate of 1000 acres in any one place, provided such estate be the property of the Crown and not of a native or natives, and unless it contains special deposits of minerals or areas of forest which for good reasons the Government may not wish to sell. Therefore there is no hindrance in the way of modest enterprise. As to *immodest* enterprise—a single association buying up a whole province, or obtaining an exclusive rubber concession over 25,000 square miles, I for one am totally opposed to any such policy, at any rate until it has been shown that a mass of small traders and four million natives cannot between them develop the resources of their country in a manner productive of profit and happiness to all.

MOUNTAINS.

By Professor JAMES GEIKIE, F.R.S.

II.

IN a former article in the *Magazine* (September 1901) we gave an outline of the geological history of Original or Tectonic mountains. Some of these, it was shown, date back to a most remote antiquity, while others are not nearly so old—not a few having come into existence in quite recent times. It was further pointed out that, in the case of the youngest Tectonic mountains, internal structure not infrequently coincides more or less closely with external form or configuration. This correspondence is most clearly seen in recent Accumulation mountains, such as our still active volcanoes—the shape assumed by those moun-

tains being obviously determined by the arrangement of their constituent materials. Nevertheless, even active volcanoes do not escape the modifying influence of the various epigene agents of change, but are attacked in the same way as mountains of every kind, old and young alike. In their case, however, the rate of decay is usually exceeded by the rate of growth. Hence the rugged furrows and gorges, gouged out by torrents on the flanks of a growing volcano, tend to be obliterated from time to time by the products of successive eruptions. But the great chains and ranges of Folded mountains cannot thus repair the ravages effected by epigene action. The growth of mountains of this type we have every reason to believe is a very gradual and protracted process. No sooner, therefore, does upswelling and wrinkling of the crust begin than the slowly ascending surface is attacked by all the atmospheric agents of change. And so powerful and effective is this action, that if the rate of crustal movement did not exceed the rate of denudation, no mountain-range could come into existence. It would be degraded as fast as it grew. Obviously, however, crustal deformation, no matter how gradual it may be, has in many, if not in all, cases exceeded the rate of denudation. Nevertheless, so potent are the agents of erosion that they have succeeded in very greatly modifying even the youngest elevations of the crust.

Although no portion of a growing mountain-chain can escape this modifying influence, it is evident that the process of degradation must be carried on most actively along lines of water-flow. As torrents, streams, and rivers cut their way down into the massif, larger and larger surfaces of rock become exposed to subaerial action. The shattered debris, detached from cliff and mountain-slope, slowly or more rapidly enters the drainage-system, gradually becomes reduced in size, and is eventually swept away in the form of gravel, sand, and mud, beyond the limits of the mountain area. So in time profound and broad valleys are ploughed out, and these continue to be deepened and widened, as the process of mountain-making goes on. Thus in the great transverse valleys which radiate from the backbone of a growing mountain-chain, the rate of erosion keeps pace with or even exceeds the rate of rock-folding and uplift. New or secondary mountains gradually come into existence along the flanks of the primary elevations—a mountain-chain, in a word, grows by the successive addition of contiguous parallel ranges. But the large transverse rivers flowing out from the primary axis are not deflected by the younger ranges which thus slowly rise across their path. The rate of valley erosion exceeds the rate of crustal deformation, and thus mountain-range after mountain-range is successively sawn across by the primeval rivers descending from the axis of the chain.

We may therefore conceive of the growth of a polygenetic mountain-chain being continued through a long period of time—the gradually bulging and wrinkling crust being concurrently worn and furrowed by epigene action. The mountain-mass as a whole, however, continues to increase in elevation notwithstanding the ravages of frost and glaciers, of rain and torrents, of streams and rivers. Only in the valleys does

epigene action balance or exceed the elevating process. When at last all earth-movement ceases, then the mountains are steadily reduced in height, while the valleys continue to be widened and deepened, until eventually the broad mountain-land may disappear and be replaced by a gently undulating plain—a *plain of erosion*.

Many such plains are known. That they occupy the site of vanished mountain-chains is clearly indicated by their internal or geological structure. Some of these old plains of erosion, like that of the Belgian coal-fields, reach no great height above the level of the sea, while others attain considerable elevations, forming lofty plateaus. A study of such plateaus shows us that a chain of Original or Tectonic mountains, after it has experienced much denudation—after it has been reduced to its base-level and replaced by a plain of erosion—may again be uplifted. The crust may once more bulge-up, and the *plain* be gradually carried to such a height that it then becomes a *plateau of erosion*. Or, instead of being thus elevated, the plain may become submerged for a longer or shorter period of time. During gradual and long-continued submergence sediment may gather over the surface of the drowned land to such an extent that the site of the former mountain-chain may eventually be buried under a thickness of many thousand feet of stratified materials—gravel, sand, mud, etc. Subsequently the movement of depression ceases, and may be replaced by movement in the opposite direction—a general bulging-up or elevation of the area may take place. Should such ensue, then the buried plain of erosion will again rise out of the sea, and may even attain a height of many thousand feet above that level. In that case we should speak of the newly formed plateau as a *plateau of accumulation*. A section across it would show that the upper portion of the elevated area consisted of a great thickness of approximately horizontal strata resting upon and concealing the old plain of erosion.

Although Tectonic mountains tend to be gradually ground down to their base-level—it is seldom that the cycle of erosion is quite completed. Long before the mountains have entirely vanished, renewed crustal deformation may take place, and the much denuded area be either re-elevated or submerged, according as the earth-movement is up or down. In the former case we get a plateau of erosion, the surface of which may be more or less irregular, ribbed and knotted with the straggling cores and stumps of the ancient mountains. In the latter case, the sorely denuded mountain-land, carried down below sea-level, becomes in time covered with sediments underneath which the lower-lying parts of the plain of erosion may eventually become very deeply buried. Should the cores and stumps of the old mountains remain above sea-level as islets, they will of course escape burial, only to be subject, however, to continuous erosion. But should they be submerged, then they also will in time become partially or entirely concealed under gradually accumulating sediments. At a later period, should the sunken area be re-elevated to a very considerable height, we shall have a plateau of accumulation, consisting of approximately horizontal strata resting upon the irregular surface of the old plain of erosion. The horizontal strata will

naturally attain their greatest thickness upon the lowest-lying portions of that plain, and will thin away as they approach the stumps of the degraded mountains—the summits of which may even peer above the surface of the plateau, as so many islets in a far-stretching sea.

Examples of all these several stages and conditions are met with again and again, but it is not necessary for our purpose to go into detail. For the present it is sufficient to realise the fact that plateaus are of two kinds—namely *plateaus of accumulation*, and *plateaus of erosion*. The former consist of horizontally disposed strata, often resting upon and partially or wholly concealing an ancient plain of erosion. The latter are built up of inclined and disturbed rocks. In the case of the former, therefore, the shape of the ground is determined by the horizontal arrangement of the strata: in the case of the latter there is no coincidence between external form and internal structure.

Now it need hardly be said that plateaus, like all other land-forms, are in time modified by erosion. Just as Tectonic mountains of every type pass through a cycle of denudation, which may or may not be interrupted by earth-movements, so a plateau becomes in like manner the prey of the epigene agents, and may eventually be reduced to its base-level. After a plateau has been deeply incised by streams and rivers—when it has become traversed by a whole network of valleys, it gradually loses the appearance of a table-land, and assumes that of a truly mountainous region. This transformation is wholly the result of denudation. The mountains and hills are not Original or Tectonic, but *Subsequent* or *Relict*. They have not been constructed or built as moun-

FIG. 1.—Relict Mountains carved out of a Plateau of Accumulation. *a, a*, Original surface of plateau.

tains, but are merely remaining portions or fragments of a formerly more extensive elevated area. They have been carved out of an old table-land and shaped into mountains by the gradual removal of masses by which they were at one time surrounded.

The form assumed by *Relict* mountains depends mainly upon the nature and arrangement of the materials out of which they have been carved. A plateau of accumulation, for example, tends to be cut up into a series of pyramidal or tabular mountains, and crested or flat-topped ridges, separating the various valleys from each other. And as the latter are deepened and widened, the massive segments of the old plateau become progressively narrower and gradually reduced in height. At a later stage most of these mountainous segments may have disappeared and only a few isolated cones and ridges or truncated pyramids may be left. Finally, every height may be levelled, and the old plateau be replaced by a plain of erosion.

In the north-west of Scotland we have excellent examples of *Relict* mountains carved out of an ancient plateau of accumulation. In that

region certain old crystalline rocks (Archæan gneiss, etc.) had at a very early geological period been reduced to a base-level. The plain of erosion thus formed was then slowly submerged, and became in time covered with a great thickness of red sandstones. Long afterwards the whole region was re-elevated, thus forming a plateau of accumulation, the upper portion of which consisted of thick red sandstones resting on the surface of a plain of erosion composed of Archæan gneiss. So prolonged a period has elapsed since that epoch of elevation that the red sandstones have been largely removed, and much of the old plain of erosion has been re-exposed. Very considerable masses of the overlying red sandstones, however, still remain, forming isolated cone-like or pyramidal Relict mountains, such as Canisp, Soulvain, Stackpolly, and Coulmore, or more closely associated aggregates of similar-shaped heights, such as the Torridon Mountains.

Having glanced at the general character of Relict mountains which have been carved out of a plateau of accumulation—that is, out of an extensive elevated mass of horizontal or approximately horizontal strata—we may now shortly consider the character of the mountains which are carved out of a plateau of erosion. The relatively level surface of such a plateau, as we have seen, is the result, not of sedimentation but of denudation. A plateau of erosion may consist of many different kinds of rock, arranged in almost any way. In not a few cases, as we have seen, such plateaus represent the sites of vanished chains of Tectonic

FIG. 2.—Diagrammatic Section of Plateau of Accumulation superposed on Plain of Erosion. *E, E*, Plain of erosion, replacing a chain of Folded Mountains; *T-R*, Torso-relict Mountains—the worn stumps of the former mountain-chain; *P, P*, Plateau of Accumulation—horizontal strata, out of which Relict Mountains (*R, R*) have been carved.

mountains. Externally they have a plain-like surface, internally they frequently show all the confused and complicated structures which are characteristic of true mountains of upheaval. Plateaus of this kind are well represented in Europe. The Highlands and Southern Uplands of Scotland, the Rhenish Schiefergebirge, the Scandinavian Mountains are all examples of highly denuded plateaus of erosion.

At a very early geological period lofty ranges of Tectonic mountains extended over what are now our Northern Highlands and Southern Uplands. During prolonged ages those ancient Caledonian ranges were subject to erosion, until eventually they were largely reduced to their base-level—only a few sorely wasted stumps and cores projecting above a gently undulating plain of erosion. Subsequently depression ensued, and the plain of erosion became, over considerable areas, more or less deeply buried under sedimentary deposits. To trace the geological history in detail is here impossible—it is too long a tale to tell—and we need do no more than realise the fact that eventually all the depressed areas were again re-elevated *en masse*.

The Highlands and Southern Uplands then appeared as plateaus.

Their configuration was upon the whole plain-like, the peripheral areas being to some extent occupied with approximately horizontal sedimentary strata, resting upon and concealing the old plain of erosion. In the central and more elevated portions of the plateaus that old plain formed the surface, and appears to have been here and there diversified by more or less abrupt heights, the worn and abraded torsos of the ancient Caledonian Mountains.

In the course of long ages the plateaus in question have experienced excessive denudation. To such a degree, indeed, have they been trenched and furrowed by multitudinous valleys, that they are now hardly recognisable as table-lands; their original plain-like character is well-nigh lost. They have been carved into rolling uplands, into regular ranges or

FIG. 3.—Relict Mountains carved out of Contorted Strata. [Section of a portion of the Southern Uplands of Scotland; after Messrs. Peach and Horne.]

irregular groups and masses of Relict mountains, the configuration and distribution of which have been determined very largely by the nature of the constituent rocks and the mode of their arrangement.

Sometimes, as throughout the larger portion of the Highlands and Southern Uplands, the Relict mountains have been sculptured out of the highly folded rocks forming the old plain of erosion; in other places, they are simply remaining portions of the younger rocks which overlie that plain; while, in not a few cases, the upper part of a mountain consists of the younger, and its basal portion of the older, rocks, the line separating the two series representing the old plain of erosion.

The forms assumed by Tectonic (folded) mountains, during the stage of early youth, are a more or less direct expression of their internal structure. The ranges coincide to some extent with upward folds (anticlines), and the intervening parallel hollows with downward folds (synclines). (See Fig. 4.) But with increasing age this approximate correspondence

FIG. 4.—Symmetrical Flexures of the Jura Mountains. The ridges coincide with Anticlines, *a, a*; the parallel valleys coincide with Synclines, *s, s*.

between configuration and structure gradually disappears, until eventually every coincidence of the kind vanishes. Under the long-continued operation of the agents of erosion, the mountains are completely remodelled. (See Fig. 5.) When a mountain-chain has passed the age of maturity, the distribution and shapes of its component heights are determined directly by the character of the rocks and their geological structure. In this respect, therefore, highly denuded Tectonic mountains do not differ

from Relict mountains which have been carved out of an ancient plateau of erosion. In both cases it is the character or nature of the rocks and the mode of their arrangement which determine the position of the heights and their general configuration. Nevertheless, we must distinguish between the two kinds of mountains. A Tectonic mountain-chain remains *original* throughout all stages of its existence; it is a true Deformation mountain-chain until it is at last swept away, and replaced by a plain of erosion. A Relict mountain has not been built up, nor is it the direct result of crustal deformation. It owes its existence to erosion;—it is a mountain of circumdenudation. But the very causes

FIG. 5.—Appalachian Ridges of Pennsylvania. The ridges coincide with Synclines, *s, s*; the valleys coincide with Anticlines, *a, a*.

which have determined its existence must eventually work out its destruction.

We have referred to the forms assumed by mountains which have been carved out of plateaus of accumulation—pyramids, and truncated pyramids being the typical shapes of such mountains. Under favourable conditions, mountains of this kind often ascend in a series of abrupt terraces, or corbel steps. But much depends on the nature of the rocks. If the strata be more or less homogeneous in character, the step-like outlines are not likely to be pronounced. Instead of abrupt pyramidal heights we may have smooth rounded hills. The character of the climate has also a powerful influence—an arid climate fostering the formation of more or less abrupt pyramidal mountains; while under moist conditions the configuration of the heights tends to be smoother and less abrupt. Nevertheless, whether the horizontally bedded rocks be of one kind or another, or show alternations of many different kinds, and whether the climate be dry or humid, equable or the reverse—tropical, temperate, or arctic—the mountains and hills carved out by the action of the epigene agents are of the same type.

Relict mountains derived from the erosion of folded and contorted rocks have, as already shown, the general aspect of highly denuded Tectonic mountains. Hence sometimes we find them extending in the direction of the outcrops of the more durable rock-masses, and thus forming more or less regular ranges. In other places, again, owing to the presence of confused and complicated structures, the heights may exhibit little or no trace of alignment, although it is obvious that in this case as in the other, the position of the mountains has been determined by the nature of the rocks and their arrangement.

But all plains and plateaus do not consist either of horizontal or of highly contorted rocks. Between these two extremes of rock-structure there are many gradations. The degree of crustal deformation varies indefinitely. There are wide regions throughout which the rocks show only long, gentle undulations—the inclination of the strata from the horizontal not exceeding a few degrees. The Midlands of England, for

example, are composed of rocks which have a general dip at a low angle towards the east. Throughout the Central Lowlands of Scotland, from the base of the Grampians to the foot of the Southern Uplands, steep dips are exceptional. And the same may be said of many other parts of the world. Away from regions of mountain-uplift, indeed, there are vast continental tracts throughout which the strata show little disturbance—the beds rising and falling in more or less gentle undulations. Sometimes the undulations succeed each other somewhat rapidly—in other places, the crust has been bent up in one broad depressed arch, measuring many miles across. In highly denuded countries the tops of the anticlinal arches—the crests of the undulations—have invariably been removed, and the truncated ends of the beds exposed. In other words, the shape or form of the ground does not coincide with the undulations of the strata, but is the result of erosion.

The most characteristic type of hill or mountain carved out of rocks which have a gentle dip or inclination is the *Escarpment*. For the formation of this kind of feature certain conditions are necessary. The strata must not only be inclined, but some bed or beds must be harder or more durable than the others. We may have, for example, a series of relatively soft sandstones and shales, with one or more intercalated beds of limestone or other relatively hard rock. (See Fig. 6.) With an arrangement such as this it is obvious that the outcrops of the softer strata will succumb more readily to the attack of the epigene agents than those of the intercalated harder rocks. The latter, therefore, come in time to project above the level of the former. In the following diagram the upper dotted line (*a, a*) represents the original surface—a former

FIG. 6.—Relict Hills and Mountains carved out of gently-inclined Strata. *a, a*, Original Surface of Plateau of Erosion; *b, b*, Present Surface of the ground; *e, e*, Escarpments; *d, d*, Dip-Slopes; *h, h*, Relatively "hard" rocks; *s, s*, Relatively "soft" rocks.

plain of erosion. The lower continuous line (*b, b*) represents the existing surface, where *e, e* are escarpments, and *d, d* dip-slopes. This is the type of hill most commonly met with in Central England. A glance at any geological map of the country will show that all the prominent hills and high grounds are developed along the outcrops of the Jurassic limestones and the Chalk, and thus have a general northerly or northeasterly trend. Proceeding from the foot of the Malvern Hills towards the east, we first traverse low-lying plains of sandstone and argillaceous strata, until on the other side of the Severn we reach the Cotswolds, composed principally of limestones, which as they dip gently eastwards are succeeded by a series of argillaceous beds, forming again a region of undulating plains. Continuing our traverse in the direction of the dip, we eventually encounter another broad belt of high ground—the escarp-

ment of the Chalk. This escarpment is succeeded in its turn by a low-lying region composed mostly of soft clay strata and other more or less non-indurated materials.

When the strata, instead of being inclined in one direction for long distances, are arranged in a series of gentle folds, escarpments continue to present themselves wherever relatively hard beds crop out at the surface. In this way we not infrequently find lines of escarpment facing each other, as in the well-known case of the North and South

FIG. 7.—Section across the Wealden area—a denuded Anticline.

Downs which overlook the intervening Weald. Here we have an example of a highly eroded anticlinal fold, which is always a weak structure, and readily reduced by epigene action.

Synclinally arranged strata do not succumb so easily—the structure is relatively strong, and makes a stouter resistance. The rocks so arranged are not degraded so rapidly as the same rocks would be if disposed in the form of an anticline. In short, it is with gently undulating strata as with the steeper and more abrupt convolutions of Tectonic mountains—anticlines are frequently replaced by hollows, while synclines tend to be developed into heights. (See Fig. 5.)

In fine, one may say that however simple or complex the geological structure of a highly denuded region may be, the configuration of the ground, as worked out by epigene action, has been determined mainly by the character of the rocks and the manner of their arrangement. In a word, when we have deciphered the geological structure of a country, we have at the same time discovered the origin of its hills and mountains.

THE FIRST ENGLISH MAP OF INDIA.

By C. G. CASH, F.R.S.G.S.

THE Hakluyt Society issued as their volumes for 1899 *The Embassy of Sir Thomas Roe to the Court of the Great Mogul*, edited by Mr. Foster, the Hon. Secretary of the Society. To these volumes I am indebted for some of the information and for the quotations in this article.

“The Company of Merchants of London trading into the East Indies” received its charter from Queen Elizabeth on the last day of the sixteenth century. In view of recent attempts at chronological controversy, it may be well to say that this was December 31st, 1600. By Papal Bull the whole of the Eastern half of the world had been reserved for Portuguese exploitation; but the English and Dutch, Protestant