PLUVIAL GEOLOGY, LANDSCAPE AND MAN IN THE EAST AFRICAN RIFT VALLEY.

By Prof. Dr. Hans Reck, Berlin.

The geologist has an especially attractive task when he tries to penetrate the darkness which envelopes the latest period of earth's history in East Africa, the diluvium, and the years which lead up to these modern times; because during this period man made his appearance and evolved his culture.

It is an accepted fact that man does not as a rule appear in a quasi-fortuitous manner, but that he is strictly bound to the landscape in which he lives, since the conditions of life resultant on that landscape are the roots of his existence and the cause of his cultural development. The manner of life and the wanderings of mankind are thus dependent upon climate and landscape.

Landscape is mainly modelled by two factors, first by the exodynamic forces of climate as they appear in rain, wind, moisture, and dryness, in ice and sunshine; and secondly by the endo-dynamic forces of the earth, represented by tectonics, volcanism, etc. The face of the landscape as it appears before our eyes is the result of the ever changing effects of these two counteracting groups of forces. The one endeavours to make and to build up new features on the old surface, whilst the other tries to level and to destroy all unevenness.

These connections between landscape, man, and geology, are as old as mankind itself, the study of any single one entails the study of the others. They concern fossil and prehistoric man just as much as they concern ourselves, since we all share in the products which we draw from the earth, and in our personal adaptations to the existing conditions.

Let me show you one example only which lies nearest to hand in the neighbourhood of this Capital (Nairobi). We find the harmony in the features of an old landscape and the contrast of forms where youthful forces dissect them, and impose on them their own laws of development. All around Nairobi mature forms characterise the highlands. The broad low backs of the mountains pass in gentle slopes down to equally broad shallow valleys, and everything is covered by a carpet of red, fertile soil on which the cattle and crops of the inhabitants flourish. This picture remains unaltered until we come to the margin of the Rift Valley. Here the wall of its escarpment cuts through the old highland landscape with extreme sharpness and at the bottom of the valley we find this old landscape no longer, but an entirely new array of forms. In many places this change is brought about by one great cut, more often by a succession of more or less narrow shelves.

as for example, on the road which leads from Nairobi to the Longonot volcano and so to Naivasha. Here it is abundantly clear that the new fracture in an old surface brought into existence new sharp forms along the edges of the Rift Valley, whilst the bottom of the Valley is drowned by the sediments which have collected in the fresh, deep trough. The two types of landscape, each one in itself with harmonious characters, are strongly contrasted. No transitional forms unite them. The differences between the characteristics of an aged land surface and those of the new-born, immature landscape are too great to be linked.

But now the question arises—how old is all this? And this is one of the big problems of modern East African geology. Since the eminent work of Gregory, one has grown accustomed to look for the birthday of this gigantic rift in Tertiary times. Still, with the advance of time and with the detailed knowledge of single parts of the faulted area, doubts have arisen as to whether this dating was not too distant, and during the last few years Leakey's work on prehistoric man in the Nakuru basin of the Rift Valley has given rich evidence in favour of a much younger origin for the colossal breakdown in the earth's crust of this country.

But before entering into more local details and into a part-examination of the Rift, attention must be drawn to the fact that this Fault Valley is a feature of huge regional extent, which is apparently independent as a whole from the local structures of the single countries through which it cuts. Thus its full significance cannot be appreciated within the confines of any small area; *its explanation must fit the facts and forms which we meet along its entire length.* Indeed this fracture is the biggest that we know of in any continent of the globe; almost a quarter of its circumference is cut by it. It is not even restricted to the African mass, but begins in Asia Minor, among the southern slopes of the Taurus Mountains. It passes through Syria and Palestine, where it contains the Dead Sea; it runs along the boundary between Asia and Africa where it provides the deep young trough of the Red Sea; then, repeatedly altering its direction at sharp angles, it enters the African continent for the first time in the lava-drowned neighbourhood of Afar in Abyssinia. From here dotted by volanoes and accompanied by huge outpourings of lava, it continues between Abyssinia and Somaliland towards Kenya, divides this country as it does the former German East Africa, and passes on gradually to lose itself in the south of Portuguese East Africa.

Throughout the whole of this distance the general and unexceptional freshness of its forms is the contrasting character when compared with the succession of completed, mature forms of the surrounding country, and this is the sign of the absolute unison and unity of its age, its history and its existence. Indeed, the uniformity of its appearance, no matter what the rocks through which it passes

consist of, illustrate this point in the clearest possible manner. Another character common not only to the whole length of the Rift, but to most stress-fractured areas of this planet, is the outbreak of huge volcanic masses in close connection with its genesis. When they have broken the crust and relieved their colossal sub-crustal pressure, and having accompanied the breakdown of the Rift bottom, they cool and harden on the surface and, like the blood of the human body, they close and heal the wound, and try to stabilise once more the disturbed equilibrium of the sunken rock. Great volcanoes have been built up in the course of this process all along the Rift. Domes and cones are, thanks to their elegance of form and of outline, the main contribution to the wild beauty of the volcano-tectonic landscape. Longonot and Suswa, Eburru and Menengai, where to this day hot water streams rise from the region of once active craters, are typical examples in Kenya; whilst for instance further south, in the old German East Africa, the famous Highland of the Giant Cauldrons was piled up with the wondrous picture of their broad, flat, shield-volcanoes, and their enormous concentric sinkfields in the top, such as Ngorongoro, one of the largest cauldrons in the world.

Standing close to the north of this Highland, but built up from the bottom of the Rift, the elegant tuff cone of L'Engai, the Mountain of God, is the most impressive witness to the not yet extinguished forces of the fiery depths—with its white soda streams from the top, its hot and heavily smoking solfatares in the crater, and its strong, repeated eruptions during the last fifteen years, which have lowered the top of the mountain through explosions by nearly a thousand feet. L'Engai is thus by far the most active, indeed the only still constantly active volcano of the East African Rift. Although such characters as I have mentioned undoubtedly prove the geological unity and youth of the whole Rift in its entire extent, such a grand and deep wound in the earth's surface cannot have come about all at once, literally speaking. But if we bear in mind that all the rifting, as we find it expressed in the sharp forms of the present escarpments, took place within the time comprehended by man's development, as is shown by archaeological finds and by fossil fauna, and if we can prove that the line of the Rift with its lakes favoured living conditions for man and for animals, directing their wanderings mainly from north to south during tens of thousands of years, *then we must conclude that the Rift formation is geologically not only a very young one, but also that it took place with a quite unaccustomed speed of dislocation.*

Most of our knowledge of the construction of the Rift Valley, especially in Kenya Colony, is due to the admirable work of the great pioneer in British East African geology, W. Gregory, who has given us a masterly exposition of his thoughts and results on this subject in two universally known books. He also was the first to recognise that to-day's Rift was preceded by an older, analogous structure, the

boundaries and the configuration of whose age we have as yet only a very faint idea. To-day we only know for certain that in old-pluvial times its evidently broad and soft-shaped trough was filled by a lake and its sediments, which we have called—according to Gregory's type locality, Kamasia, to the west of Baringo—the Kamasian Lake. These sediments represent, according to our latest studies in the Rift, not tertiary deposits, as Gregory thought, but the middle and older pluvial of East Africa. Such date-changings and new conceptions in no way diminish the historic value of Gregory's expositions; they were on the contrary only made possible by the existence of a safe basis of fundamental knowledge of Rift Geology which he had worked out; and are the natural result of progression and more detailed study of the structural and stratigraphical features of the country.

The man who stands out in recent years as having deciphered the natural documents of the youngest period in East Africa's geology is a son of this country, Dr. L. S. B. Leakey, who is the leader of our present expedition devoted to the same task. He approached the problem from the side of Archaeology and Anthropology. He searched systematically for years in the young sediments of the Rift for remains of human culture goods. The astonishing results and rich collections which he achieved in this way allowed him to classify his tools and implements not only according to a scale of cultures of men which followed one upon the other in East Africa, but also enabled him to classify the sediments in which they were found. Thus in the unfossiliferous beds of Kenya's Kamasian Lake implements took the place of animal fossils, which are, as yet, lacking.

I think it is one of the chief merits of Leakey's studies that from the very beginning he had realised that only in combination and full harmony with geology could his wonderful discoveries of cultures and old skeletons achieve their full scientific value, and that only from this aspect could the archaelogical result derive its most incontrovertible proofs. So, from the beginning, Leakey has always pursued his studies hand in hand with geology, and has thus given his work the firm and broad foundation which we admire in his publications, and which bears eloquent testimony to the breadth of his scientific outlook. It is also this conception of his life-task to which I am indebted for the opportunity of being a member of his recent expedition to Oldoway.

Especially at Oldoway, where there was a lake in old pluvial times separated from the great Kamasian Lake, and where there existed favourable conditions for the preservation of animal life, Archaeology and Geology have found yet a third companion to aid in the more intimate recognition of those old times, and to help in the establishment of those proofs for their true explanation. This is Paleontology. The bones of extinct animals, whose still-living relations we know, in almost all cases, bound to very distinct living

conditions, gave Mr. Hopwood, the well-known Paleontologist of our expedition, rich possibilities to amplify the pageant of terrestrial changes of human history and of the faunas of the past, and to give a wider appreciation of the climate and plant relationships of those times.

The results of this trinity of independent yet parallel researches, which were duly compared in the course of our field work, always worked in so harmoniously that no essential differences of opinion on any point of importance could persist. On the contrary, the free discussion of different meanings on single points, especially in the beginning, when our scientific work had not yet found its later stable foundation, led always to a deeper conception of the problems which arose, and at the last always found us of one mind, as we have repeatedly documented in our preliminary letters to *Nature*, October 24th and December 26th, 1931.

In these results, reached independently and harmoniously, we see furthermore the strongest possible proof of the correctness of our observations and deductions.

This triple research led to amazingly rich results, especially at Oldoway, to the further exploration of which—in continuation of my 1913 expedition—we had set out. Let me therefore shortly draw your attention to this unique area, as the best and most typical example of Pluvial Geology, Paleontology, and Archaeology known, up to now, in the East African Rift zone.

Oldoway is situated to the south of the Kenya border, at the western foot of the Highland of the Giant Cauldrons. Its special attraction for us, which has led up to this expedition, was the rich fossil fauna which its sediment contained, in one place associated with a fossil human skeleton. Human culture relics were, at that time, lacking and it remained for Leakey to discover and study them in the course of our common work on this expedition.

Oldoway is in many respects an intermediate link between the young volcanoes in the east and the primeval plains of the Serengeti in the west. All over this huge peneplain hills and valleys have been smoothed out, often smothered by a blanket of detritus, changed into a monotonous wide evenness devoid of rock, frequently even of trees, for many miles around. There is an ocean of pasture inexhaustibly rich in game, which alone enlivens the monotony of this landscape stretching out limitless to the eye. The process of peneplainisation can well be grasped from the intermediate forms between the plain and its hilly frame, which we passed between Oliondo in the north and Oldoway. These plateau remains, Inselberge, detritus-drowned rock-peaks, all these witnesses to a process of dissection, decomposition, destruction of mountains, also show that the great plains west of the Rift are not old dead forms, but still growing features of the landscape.

But the origin of the Oldoway sediments has nothing to do with this process of peneplainisation. Their material was mainly derived from the volcanic Highlands in the east, both directly by volcanic eruption and transport through the air, and indirectly by river and flood transport of hillwash from the exposed surfaces of the volcanoes in the East.

Thus the history of both are in closest connection in point of time, as well as in genesis, *and out of this relation the first proof of the unexpected youth of the Rift Valley could be deduced.*

For the Highlands of the Giant Cauldrons is—at least in its youngest volcanoes—younger than the Oldoway sediments in the west and at the same time also older than the great faulting in its east, where the Rift escarpment cuts through all the Highland volcanoes in its course, regardless of their form, material height, or position. The faulting which upheld the Highlands as a rigid block between relatively long and narrow strips of sunken land is the youngest chapter in this part of the country's geological history.

The accessory rift along the western front of the Highland is but a small and shallow one. Slowly developing its forms from the north, it ends abruptly in front of the old Lamagrut volcano in the south, the resistance of which evidently could not be broken by the genetic forces of this small sink strip. But it must be borne in mind that the deep trough of Eyassi Lake on the opposite side of Lemagrut is the immediate continuation of this small northerly rift, which is named Balbal.

Whilst the faulting of the Balbal is not very clearly demonstrated along the greatest part of its limit against the Eastern Highland, because fresh volcanic material and detrital sediments combine to obscure it, it is all the more distinct along the western side, where in the Oldoway Gorge a whole series of fault-steps leading down from the Serengeti to the bottom of Balbal are beautifully exposed in every detail.

The astounding consequence of all these facts is that throughout the time when Homo Sapiens lived in the Oldoway region and developed his stone tool culture from the very rudest chipped pebbles to the most perfect forms of *coups de poing* during the time, and parallel with, the deposition of the Kamasian Oldoway lake sediments, *there was no Rift Valley yet formed, in the present sense of the word.*

Nevertheless, the much older birth of its structure was sketched by the existence and growth of a parallel line of older volcanoes. These built up a dam and a new watershed towards the east, and thus gave origin to the Kamasian Oldoway Lake, as they delivered the material to fill up the new water basin with the series of sediments then preserved. It is these which now contain the unique and exceptionally rich fossil documents of lower pluvial times; the collection and study of which was the main task of our expedition.

When these events are said to have occurred in the middle and older pluvial period, this statement rests—as we have seen—not merely on local factors, but is also based on the regional geology of East Africa. But it is not even deduced from geology alone. It is harmoniously supplemented by the archaeological and paleontological finds. Let us take an example from the latter. *Elephas antiquus*, found in masses at Oldoway in its local race of *Elephas antiquus Recki*, is an especially characteristic member of the middle pleistocene faunas of the whole of Asia and Europe. The same argument applies to the human cultures. The Chellean type of tools, so widespread at Oldoway, is to be found in many places of the old world, but everywhere it marks the same distinct period in the succession of progressing human cultures, a fact which times it not only relatively, but in most cases, where something more is known about the evolution of mankind, also absolutely within narrow limits. Admittedly, when considered quite by itself, or within the narrow limits say of centuries, an exact timing is not possible. For an animal or a culture may have existed in one portion of the globe even thousands of years before it did in another, and thus gives no absolute criterion of age. But characteristic types, when considered from a more comprehensive and from a comparative aspect unite to form great and general evolutionary series, which as a unit must, and always does, fit harmoniously into the major geological time scale, and thus the individual components find their true positions in the whole system with sufficient exactitude for geological research.

Now, at Oldoway the young gorge, to which this name was given, cuts the pluvial sediments from top to bottom and thus enables us to see and to read the documents which Nature has preserved there. It shows the predominance of explosion-ejectamenta in the material, it shows well stratified ashes and marls, partly with fish remains, as they were deposited in the old lake. It shows not less distinctly the contributions of the dry land in the east to the deposits: pebble bands and sands with rolled lava fragments from the volcanic Highlands, or quarzites derived from near-by Inselberge of the old ground formations. Last and not least, are the thousands of bones and skeletons of terrestrial animals which were found washed in from the shores into the bottom sediments of the lake.

At last, gradually the lake dried up; sedimentation stopped. A new chapter in Oldoway's history began, earthquakes shook the land, new volcanoes raised their chimneys on the Highlands, the simple succession of the now dry lake sediments was cut through and disturbed by faulting. *The Balbal depression—accessory to the main Rift further east—began to founder.*

Only after this tectonic main phase we enter the period of the younger Pluvial. Leakey has in previous studies, for instance at Gamble's cave on the margin of the Nakuru basin of the Rift, re-

peatedly emphasised this fact, and our last month's common work in this and the neighbouring basins of it have proved anew the full correctness of this statement. Of human implements the Mousterien and Aurignacien—contemporary in East Africa—are the main representatives of the technique of young diluvial man in the Rift area. In Paleontology the high percentage of still living, the lack of entirely extinct species and genera, is the most characteristic fact. The geological aspect shows a series of either volcanic or marly sediments, mostly brownish in colour, and entirely bound to the new sedimentation trough of the Rift, whilst the country above its steep edges now belonged to the area of subacrial destruction and erosion of previously formed deposits.

Exactly the same process took place at Oldoway. The deep-lying bottom of the Balbal depression was, and is still now, filling up with fine sand and dust, partly water, partly wind-borne. Details of these deposits are not known, as no section is exposed by erosion through these sediments.

Opposite the Balbal depression in the higher region of the Oldoway gorge itself there was less accumulation, there was rather destruction of older pluvial material. A pre-Oldoway gorge-valley was cut through the Kamasian fossiliferous deposits, unconformably overlain and then partly filled up again, in a dry part of the climatic circle, mainly by wind-blown dust and sand, containing few fossils only, of which landshells are predominant. These scanty deposits, compared with the rich formation of lower pluvial sediments, show most clearly the dependence of sedimentation on favourable climatic conditions, and they show with what thoroughness these had changed between the older and younger pluvials. Thus Oldoway, which had proved to be the best possible type locality for the Kamasian will never be of equal importance for the study of the Gamblian, i.e. younger pluvial time, for which Leakey has found rich sites in different parts of the Kenya Rift zone.

As faulting and volcanic activity grew less and less in the main rift during young and post-pluvial times, the more we approach our own times, so it did in the accessory area of Oldoway. The dust formation on the great plains, and its transport to the deepest accessible localities is still going on, but parallel with it the dissection of the previously laid down sediments progresses on a grand scale. The forces of this grand destructional work are drawn from the strong seasonal rains of the country.

They created the latest and most striking feature in the old face of the Oldoway landscape, the cutting and present-day modelling of the deep and picturesque gorge, which alone enabled us by its clear and simple sections to penetrate so far into the dark of its dissected and re-opened sediments, and into the varied geological details of its pluvial history.

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