

SUPPLEMENT TO THE
GEOLOGICAL MAGAZINE

FOR JULY, 1904.

*ON THE ORIGIN OF THE MARINE (HALOLIMNIC)
FAUNA OF LAKE TANGANYIKA.*

By W. H. HUDLESTON, M.A., F.R.S.

(Vice-President, Victoria Institute.)

[*With Two Plates.*]

A Paper read before a Meeting of the Members and Associates of the Victoria Institute, on May 25th, 1904, and published in this Magazine, by kind permission of the Council, in advance of the annual volume of their Transactions for 1904.

CONTENTS.

PART I.—GENERAL CONSIDERATIONS: ZOOLOGY AND PALEONTOLOGY.

Introductory.

History of the subject and statement of Mr. Moore's views.

The argument limited to the halolimnic gasteropods—Appendix on the Conchology.

Distribution of Jurassic faunas in intermediate areas—African Jurassics.

Character of freshwater faunas.

On the possible transference from marine to freshwater conditions.

Jurassic fossils of the Mediterranean basin.

PART II.—OUTLINES OF AFRICAN GEOLOGY.

The three principal geographical divisions.

The Plateau-range of East Africa (the Great Central Range of Mr. Moore).

Geology of British East Africa.

Geological structure of the Congo basin.

The periphery of the Congo basin.

Suggested correlation of the beds composing the interior of the basin.

Structure of a Graben.

Geology of Lake Tanganyika.

PART III.—CONCLUSIONS.

1. The zoological aspect.
2. The palæontological evidence.
3. The argument from geology.

VICTORIA INSTITUTE TRANSACTIONS.

A

NOTE.—It should be observed that the title of this paper is rather unfortunate since it starts by begging the question of a marine origin. I consented to write a paper for the *Victoria Institute* on the “Tanganyika Problem,” and this I have endeavoured to do, so far as available information will allow me, but I admit at the outset that many years of observation must elapse ere the Tanganyika Problem is fully solved.

PART I.

GENERAL CONSIDERATIONS, ZOOLOGY AND PALÆONTOLOGY.

Introductory.—Fifty years ago Central Africa itself presented a problem, which as far as geographical exploration extends, was ripening for solution at the hands of the bold explorers of the latter half of the nineteenth century. By degrees the wonders of the Dark Continent were revealed to the geographer and the naturalist, and even the geology of those regions has received some share of attention, rather by way of comparison with the already known features of more accessible districts, such as the Cape, than for any detailed and systematic description of the rocks which constitute their surface. Although missionaries of German origin contributed materially to our early knowledge of East Central Africa, still the larger share of exploration has fallen to the lot of our own fellow-countrymen.*

When the geographical features became better known, it was ascertained that this once mysterious region contained numerous lakes of immense size, some of them situated in deep chasms of the earth's crust. And, more unexpected still, it was found that there were volcanoes both extinct and active, constituting lofty mountains; and furthermore that on some of these mountains glaciation had been developed on a considerable scale, and that glaciers even now exist on the higher peaks, actually under the equator.

What wonder, then, that Equatorial Africa, and particularly the eastern portion of it, should present problems, both in geology and zoology, which are difficult of solution? As for ourselves we must admit at the outset that we are entirely dependent on the descriptive portion of those numerous and excellent works, which tell us of this country; and if we venture in any case to hesitate at accepting all the inferences

* One of the greatest of whom, Sir H. M. Stanley, has just passed away; to the general regret of all from the King downwards. Sir Henry Stanley was a Hon. Corresponding Member of the Institute.—E. H. (Ed.)

which their authors have drawn, it must be with bated breath and with the full consciousness ever present in our minds that they have been there and that we have not. In the light of so much that has recently been revealed, it is only natural that many controversies should arise and some of these perhaps may be ultimately settled by more extended investigations leading to further knowledge of the subject. As a case in point, I may mention the remarkable circumstance which has greatly exercised the minds of certain zoologists, viz.:—that there are some species of fishes in the waters of the Upper Nile which also occur in the hydrographic basin of the Jordan in Palestine, and yet are not found in the waters of the Lower Nile in Egypt. When zoologists are desirous of accounting for anything which seems abnormal or difficult of explanation, they are quite prepared to make the earth's surface undergo considerable modifications in order to suit their special line of argument, and indeed they can generally find a sufficient number of geologists to back them in such a course. This subject may crop up again when we proceed to consider the geological structure of eastern Equatorial Africa, and, therefore, it will be sufficient at the present moment merely to refer to the hypothesis, which connects the drainage of the Jordan system, through the Gulf of Akabah and the valley of the Red Sea, then supposed to be a fresh-water river, with a portion of the "Rift Valley" system, and ultimately with the drainage of the Upper Nile. Far be it from me to say that such an explanation is incorrect, but it certainly ignores all existing hydrographic arrangements most completely.*

The case I have just quoted is perhaps more difficult of solution than the problem which we are now called upon more especially to consider, viz.:—the origin of the halolimnic fauna of Lake Tanganyika, or in other words what Mr. Moore very aptly calls the "Tanganyika Problem." In attempting to grapple with this very curious and interesting question, besides the zoological evidence, it will be necessary to consider the geological structure of Equatorial Africa as far as the scanty details of our present knowledge permit; and if we venture in this connection to attempt to trace any portion of its physical history in times past, such reconstruction should harmonize as much as possible with known facts and existing features.

* On this subject the reader is referred to a paper "On the physical conditions of the Mediterranean Basin, which have given rise to a community of some species of fresh-water species in the Nile and in the Jordan Basins." *Trans. Vict. Inst.*, vol. xxxi, p. 3 (with map).—E. H. (Ed.)

History of the subject and statement of Mr. Moore's views.—The history of the recognition of the halolimnic fauna is important as tending to show what were men's views from time to time as each step in the progress of discovery was made. It will be remembered that Lake Tanganyika was discovered by Burton in 1857, and that his companion, Speke, picked up a few dead shells from the shores and brought them to England. The well-known conchologist, Dr. Sam. P. Woodward (*Proc. Zool. Soc.*, 1859, p. 348, Pl. XLVII) was struck with the peculiar forms of some of the gasteropods, which he considered had a certain marine look about them. Subsequently when further supplies were procured, Mr. Edgar Smith (*Proc. Zool. Soc.*, 1881, p. 276), in a paper on a collection of shells from Lakes Tanganyika and Nyassa, expressed an opinion that they might turn out to be the relics of a former sea. The subsequent discovery of medusæ in Lake Tanganyika seemed to confirm these views as far as that lake was concerned. Hence before Mr. Moore appeared upon the scene most of those who had paid attention to the subject had expressed themselves as favouring the view of the marine origin of this peculiar fauna.

Mr. Moore, as a result of his first journey in 1896, found "that in Nyassa and Shirwa there were no jelly-fishes, nor anything except purely fresh-water forms; while in Tanganyika there were not only jelly-fishes, but a whole series of molluscs, crabs, prawns, sponges, and smaller things, none of which appeared in any of the lakes he then knew, and all of which were distinctly marine in type.* Further than this, however, he found that none of these strange marine looking animals were to be compared directly with any living marine forms, yet, in their structure, some of them certainly seemed to antecede a number of marine types in the evolutionary series, and, in consequence, they appeared to hail from the marine fauna of a departed age. The most definite result of the first Tanganyika expedition, therefore, appeared to be that the sea had at some former time been connected with the lake, but when or how remained a mystery."

The above are Mr. Moore's own words in explanation of his views after the termination of his first expedition. It should be borne in mind that at this period, viz., in 1898, when his inferences were laid before the Royal Society (*Proc. Roy. Soc.*, vol. 62), there was an idea then partially and perhaps generally prevailing, that owing to the peculiar structure of the Rift-

* J. E. S. Moore, *The Tanganyika Problem* (1903), p. 3.

Valley system and its obvious physical connection with the great Red Sea depression, that the "halolimnic" fauna might have entered Lake Tanganyika from that quarter, and would consequently be found in some of the Rift-Valley lakes to the northwards, and especially in Lake Kivu, with which at the present day Tanganyika is hydrographically connected through the River Rusizi. It was therefore indeed a surprise when Mr. Moore had to announce as the result of his second expedition, commenced in the spring of 1899, that no trace of the "halolimnic" fauna had been discovered in any of the lakes, such as Kivu, the Albert Edward, or the Albert Nyanza, which lie to the northward of Tanganyika in the western arm of the Rift-Valley system. Nay, more, it would seem that no such thing as the halolimnic fauna was to be found in the great upland basin of the Victoria Nyanza, nor in the chain of lakes associated with Lake Rudolf (Basso Narok), which lie towards the northern termination of the eastern arm of the Rift-Valley system.*

To quote Mr. Moore's own conclusions on this point: "It has been shown that throughout Equatorial Africa, as in other great continents, there is a normal fresh-water fauna which has nothing peculiar about it Subsequently, the fauna of L.

* There appears to be no longer any doubt as to the presence in Lake Victoria Nyanza of medusæ indistinguishable from those of Lake Tanganyika, and the fact cannot be without its effect upon the acceptance of the view put forward by Mr. J. E. S. Moore that the fauna of Lake Tanganyika differs from that of the other East African lakes in alone possessing evidences of a marine origin. On December 1, 1903, Prof. Ray Lankester exhibited at the Zoological Society some medusæ from Victoria Nyanza obtained by Mr. Hobley on August 31, 1903, and sent to London by Sir Charles Eliot. A doubt being raised by some supporters of Mr. Moore's theory as to these medusæ having really come from Lake Victoria and not from Lake Tanganyika, Sir Charles Eliot, in a letter dated Mombasa, December 20, 1903, wrote to Prof. Lankester saying that the medusæ were collected by Mr. Hobley himself, in the Kavirondo Gulf, by the side of which the railway terminus is situated, and that the water was full of them. Mr. Hobley, at the request of Sir Charles Eliot, had endeavoured to study the life-history of the medusæ, but he failed to keep them alive for more than a few days. The specimens sent to London were said by Mr. R. T. Günther to be indistinguishable from the *Limnocyclus tanganyicæ* of Lake Tanganyika. It is interesting in this connection to note that the Victoria medusæ were discovered quite independently in the same locality (Kavirondo, in the Kisumu district), and apparently at about the same time of year. According to *Globus* (January 28, p. 84), M. Ch. Alluaud, on the day of his arrival at Lake Victoria, discovered a marine medusa similar to that of Lake Tanganyika, and communicated an account of his discovery to the Paris Geographical Society on September 19, 1903.—*Nature*.

Tanganyika has been examined in detail, and it has been shown that this lake, like all other great lakes of Central Africa, contains the ordinary fresh-water fauna of the continent; but that in Tanganyika, and in Tanganyika alone, there are a number of organisms possessing definitely marine and somewhat archaic characters. Along with these, the halolimnic members of the Tanganyika fauna, there are others, such as the prawns, sponges and protozoa which, although not like the previous types, unique in being found in Tanganyika for the first time as fresh-water forms, are notwithstanding probably portions of the same group, for they are peculiar to Tanganyika, and are not characteristic of the general fresh-water fauna of the African continent." He further suggests that the African ganoids and certain other members of the African fish fauna may be portions of the "halolimnic" fauna. Lastly, he points to the significance of the similarity which subsists between the shells of the halolimnic gasteropods and "the remains of those found in the deposits of the old Jurassic seas."

Thus far Mr. Moore. When we ourselves attempt to face the *Tanganyika Problem*, it is obvious that it will have to be considered both from a zoological and a geological point of view, and the question is which shall we consider first, the zoology or the geology? We are dealing with an exceptional fauna, occurring under peculiar conditions and in what was, until quite recently, a most out-of-the-way place. Perhaps the first question we should ask ourselves is this: Do we consider that there is sufficient evidence of the marine origin of the halolimnic fauna? This fauna is placed by Mr. Moore himself under two different categories. (1) The halolimnic gasteropods, which are thought to be homœomorphic with certain shells from beds of the Inferior Oolite formation in Western Europe, and are thus inferentially regarded as descendants of those forms. (2) A fauna, not so thoroughly exceptional as the halolimnic gasteropods, made up of prawns, sponges, protozoa, etc., which are archaic in type and may be portions of the same group of marine derivatives. The presence of *Medusa* also is held greatly to strengthen this view. As regards the portion of the argument relating to the fishes it has been stated by a competent authority that the fishes described by Mr. Boulenger in Mr. Moore's beautiful book are all essentially present day types, and do not in any way represent survivors from the seas of the Mesozoic period.*

* *Geological Magazine*, September, 1903, p. 418.

The argument limited to the halolimnic gasteropods.—Although, therefore, the subsidiary fauna of exceptional character may help to strengthen the argument in favour of the marine origin of the entire halolimnic group, yet the most important link in this chain of evidence is to be sought in the *halolimnic gasteropods*, which are considered so greatly to resemble Inferior Oolite forms, and which on the strength of this resemblance are held to be derived from a well known gasteropod fauna of Jurassic age. The malacological evidence, as regards the Tanganyika species, has been well worked out by Mr. Moore, and the conclusions as to the peculiar mixed and to a certain extent archaic structure of their anatomy must undoubtedly have great weight. But at this point the argument fails us, for when we are disposed to institute a comparison between living and fossil species we must in the main fall back on conchology alone. One point of importance must be noted here, viz., that, since the connection between the halolimnic fauna of Tanganyika and the old Jurassic marine fauna is confined to univalves, one might almost have expected that some lamellibranchs, and particularly *Trigonia*, if only in a modified form, might have accompanied their molluscan relatives. For it can hardly be contended that *Trigonia* would suffer more from translation to fresh-water conditions than the numerous species of gasteropods which are correlated with Jurassic forms. Moreover, if conchology is to be our guide in this matter, it is to be regretted that the author of the "Tanganyika Problem" should have endeavoured to minimize the value of a branch of science on which his conclusions with reference to the Jurassic origin of these Tanganyika shells must in the main be based.*

The above considerations apart, it must be admitted that there are some genera of Tanganyika gasteropods which have a striking external resemblance of form and ornamentation to certain well-known genera which more especially characterize the Inferior Oolite of the Anglo-Norman basin; and if such resemblance is not fortuitous there seems a fair reason for regarding them as the possible descendants of such genera or their allies. Consequently, some portions of Mr. Moore's latest work are devoted to a detailed comparison between the Tanganyika shells and their presumed Jurassic analogues. The text is accompanied by excellent illustrations, the shell and the fossil being drawn side by side. As a detailed criticism of these comparisons might be somewhat tedious to the members

* *Geographical Journal* for 1903, p. 682 *et seq.*

of this Society, it will be sufficient to relegate this portion of my paper to an appendix, and briefly to state the impressions which a careful examination of both sets of shells, the fossil and the modern, have left upon my mind.*

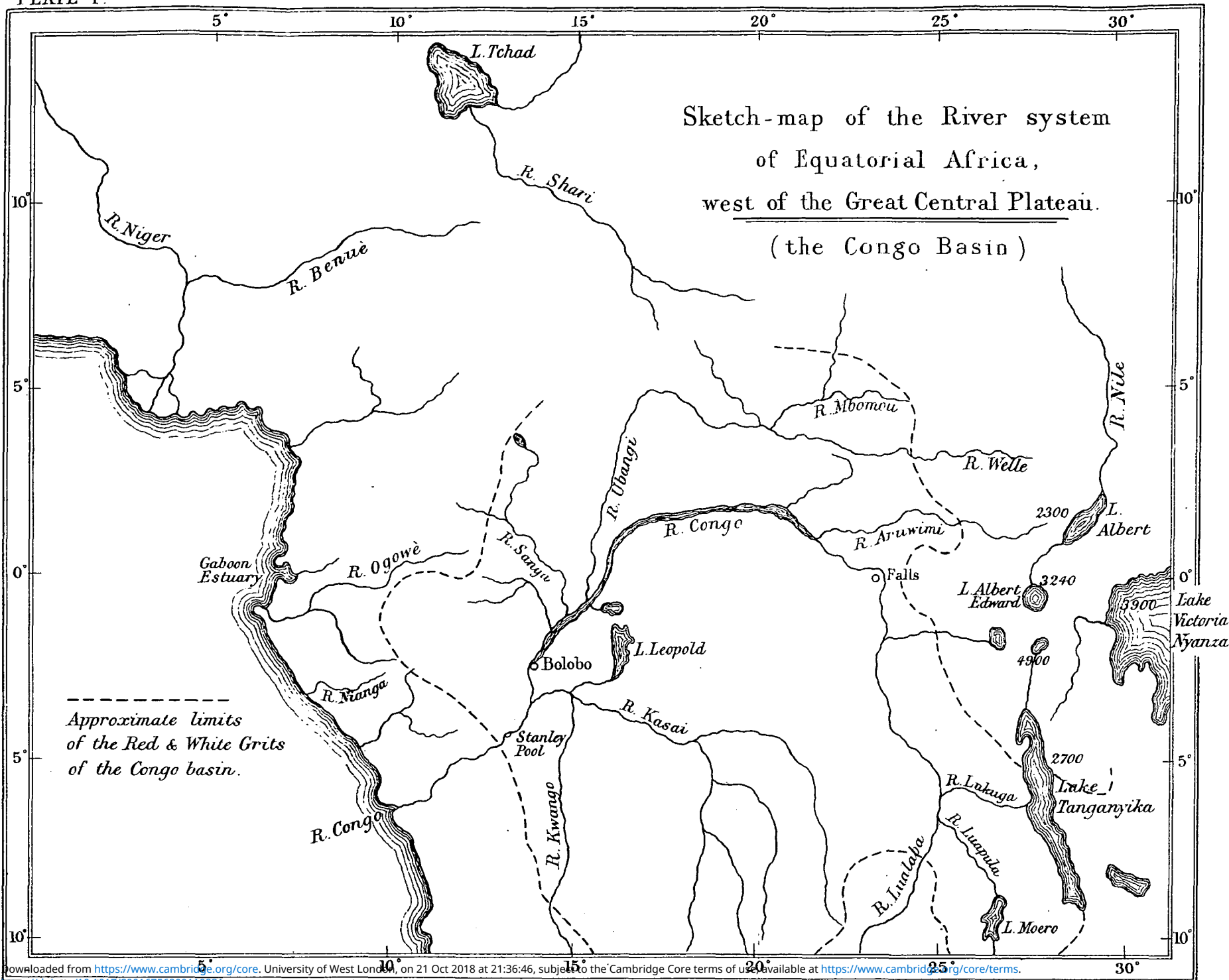
As a result of this detailed examination I find on conchological grounds, that the evidence of an ancestral connection between certain fossils of the Inferior Oolite of the Anglo-Norman basin and the following halolimnic genera, viz., *Typhobia*, *Bathanalia*, *Limnotrochus*, *Chytia*, *Paramelania*, *Bythoceras*, *Tanganyicia*, *Spekia*, and *Nassopsis*, is not nearly so strong as I had anticipated from the inferences already drawn and from what I had read in several publications. There are two Jurassic genera, chiefly developed in the Lower Oolites, viz., *Amberleya* and *Purpurina*, which have their conchological analogues in Lake Tanganyika, and in some cases the resemblance is very striking. But this is scarcely sufficient to justify the assumption that the oceanic character of these Tanganyika molluscs will more or less necessitate that the Tanganyika region of to-day must have approximated in character to an arm of the deep and open sea in ancient times,† and the inference is in Jurassic times. Indeed some people, I believe, have gone so far as to describe Tanganyika as an arm of the Jurassic sea. On biological grounds alone this is not at all probable; because under any circumstances this would have been a different zoological province from that occupied by the Anglo-Norman basin in Jurassic times.

It is further pointed out in the appendix, that, besides the resemblance between Jurassic and Tanganyikan gasteropods noted by Mr. Moore, there are other cases of what I have regarded as mere mock resemblances; but in order to appreciate such cases it will be necessary to study the appendix closely, which the majority of the members probably will not be inclined to do.

On the whole, taking the evidence of the *Medusa*, and the other semi-marine forms, as well as that of the halolimnic gasteropods themselves, a fairly good *prima facie* case for the originally marine origin of these exceptional organisms has been made out, nor do these curious gasteropods appear to be in any degree of close relationship with their ordinary fresh-water companions, although most of them undoubtedly bear traces of a long probationary experience of life in fresh-water. This may

* Appendix to Part I.

† *Proceedings Royal Society*, 1898, p. 455.



be seen in the texture of the shells, the colouring, the condition of the epidermis, etc., which may be noted in some of, but not in all, the genera.

The strongest argument of all in favour of an exceptional original is the fact that, so far as is known at present, the halolimnic gasteropods are confined entirely to Lake Tanganyika, and this circumstance will incline us to look to the Congo basin, as being the place where the mystery may some day be solved.*

Before attempting to grapple with this part of the subject which will involve the study of the geological structure of large portions of Equatorial Africa, there are two independent considerations on which I might say a word.

Distribution of Jurassic faunas in intermediate areas.—The first of these considerations relates to the distribution of *known* Jurassic faunas in areas intermediate between the Anglo-Norman basin and Lake Tanganyika, so far as such an investigation can be made, and thus endeavour to ascertain if this will throw any light upon the possible Jurassic origin of the halolimnic gasteropods themselves. From the quarries of Dorset to the depths of Tanganyika is a far cry and there should be some half-way houses, some stepping stones, as it were, to bridge over the vast distance that lies between them. Mere zoological conjecture, as I have already pointed out, is not sufficient. We must have some palæontological evidence in corroboration of the intimate relationship claimed to exist between the two gasteropod faunas, *i.e.*, between the real fossils and those molluscs which are only archaic in their internal development. In the first place, then, I may say that in this country the peculiar gasteropod fauna which characterises the Inferior Oolite of the Anglo-Norman basin can hardly be traced above the Lower Oolites, though a stray form may linger in the Callovian or even the Corallian of Yorkshire. In middle France a repetition of this peculiar fauna is seen in the Callovian of Montreuil-Bellay. When we trace the Jurassic faunas into the south-west of France, although there is much in common with parts of the Inferior Oolite of our own country, yet the analogy, as far as gasteropods are concerned, is mainly confined to such genera as *Nerinea*.

* The fact that a species of jelly-fish identical with the one in Tanganyika has recently been discovered in the Victoria Nyanza, but slightly affects the argument as regards the halolimnic gasteropods. We can scarcely doubt that the more mobile organisms have had opportunities of establishing themselves from the great centres of distribution in a way which is denied to the more sedentary molluscs.



Out of about thirty genera of gasteropods quoted in Dr. Glangeaud's list from the Lower Oolites of the south-west of France the genus *Purpurina* does not appear at all, whilst the genus *Amberleya* is restricted to a single unnamed species. On the other hand the genus *Purpuroidea* is recognised.* Going further south again, we look to Choffat for information as to the Jurassic faunas of the Iberian peninsula. Hitherto, I have been unable to come across any systematic list of the gasteropod fauna of the Jurassic beds, though I note in the *Faune Cretacique du Portugal*,† a species of *Purpuroidea* described by that author. There are, however, throughout Choffat's numerous publications many lists of Jurassic fossils, yet I can find nothing which might lead one to suppose that the peculiar Anglo-Norman facies of Inferior Oolite gasteropods can be traced in the peninsula.

There is one very rich gasteropod fauna of Lias-Oolite age in Sicily which inspired the famous monograph of Gemmellaro: "Sui fossili del calcare cristallino della Montagna del Casale e di Bellampo, nella provincia di Palermo." The gasteropod facies of these beds possesses some forms which appear specifically identical with those of the Anglo-Norman Inferior Oolite. However, there is no *Purpurina* and only one species of *Amberleya*.

On a higher Jurassic horizon in the same island, we recognise an *Amberleya*-like form in *Eucyclus alpinus*. On the whole, however, there is nothing in this assemblage which would help us to connect this gasteropod fauna specially with the halolimnic gasteropods of Tanganyika.

The above enumerations may be regarded in the light of a search after the stepping stones between the Anglo-Norman basin and Lake Tanganyika; and if there has ever existed, either in Jurassic, Cretaceous, or Tertiary times, any such connection, direct or second hand, between the region in which Lake Tanganyika is situated and the sea, as is claimed by Mr. Moore, such connection has most probably been from the northwards and ultimately by way of the Congo basin. At any rate the physical configuration of Africa seems to point in this direction; and since this is the case, any discovery of Jurassic faunas, such as those of Madagascar, though very interesting in themselves, and in reality much nearer Tanganyika, is of less

* *Bulletin des services de la Carte Géologique de France* (No. 50) vol. viii. (1896-7) p. 118.

† Vol. i (1886), p. 6, Plate I, fig. 1.

importance in considering the origin of the halolimnic fauna, being outside any possible connection with the Congo basin.

African Jurassics (Madagascar and Abyssinia).—Briefly referring to a valuable paper by Messrs. Baron and Newton on fossils from Madagascar,* we may note that the Jurassic fossils of that region are fairly numerous, the following horizons having been determined by means of the ammonites: viz., Oxfordian, Callovian, Bathonian, Bajocian and Lias. Amongst the Gasteropoda were two species of *Cerithium* from the Oxfordian. The remainder of the gasteropods were mostly from the equivalents of the Great Oolite (Bathonian), and included *Nerita Buvignieri*, M. and L. together with species of *Nerinea* and *Natica* described by Morris and Lycett; also *Solarium* and *Trochus*, and likewise a new species of Opisthobranch of large size referred by Mr. Newton to *Trochacteonina*. Along with this limited assemblage of gasteropods occur a very considerable number of lamellibranchs. A peep at Jurassic times almost under the equator is interesting in this connection, but there is nothing in the Madagascar fauna which particularly reminds us of the halolimnic gasteropods of Tanganyika.

The very important development of Jurassic limestones in Abyssinia described by Dr. Blanford, is extremely interesting from the fact that undoubted marine beds of Jurassic age have been raised, in a district situated about 10° N. of the equator, to plateau elevations of 8,000 feet. Nevertheless, owing to their apparent poverty in gasteropods, these beds throw no light upon the question with which we are at present concerned.†

Character of Fresh-water Faunas.—The second independent consideration of which I propose to treat relates to the character of fresh-water faunas, and more especially of the mollusca, and this, though a large subject, must be treated briefly. Without going back into the very remote past, we possess a considerable number of fresh-water forms, interlarded as it were with those of marine origin, in the Coal-measures. This subject has received much attention from Dr. Wheelton Hind, and it is interesting to note that most of these forms are lamellibranchs, hence they are, to a certain extent, outside the subject more especially under consideration. Gasteropoda in the really fresh-water beds of the Coal-measures are rare.

The earliest appearance of *Paludina* (*Vivipara*) in this

* *Quarterly Journal, Geological Society*, vol. 51, pp. 57-92.

† Blanford, *Geology and Zoology of Abyssinia*, 1870.

country occurs towards the top of the Inferior Oolite, where it is extremely local; and as a proof of the conservative character of some fresh-water organisms, always supposing them to have lived in fresh-water, this form is almost identical with the *Paludina vivipara* of the present day. I mention this genus as being very characteristic of fresh-water; and on the higher horizon of the Purbeck beds the genus is represented by two other species in great abundance, together with many other fresh-water genera. Nevertheless in the Purbecks, as in the Coal-measures, there are estuarine intercalations when a different set of fossils are found, and in the case of *Paludina langtonensis* from the Lower Oolites of Oxfordshire marine gasteropods occur in the same bed. The above statements supply a few facts as to the appearance in time of certain fresh-water organisms; but the question of their origin seems scarcely to have got beyond the range of conjecture. However, it is in the Coal-measures and in some members of the Jurassic system that the question of the origin of fresh-water molluscs can best be studied at present. The remarkable uniformity in general character of these organisms over very wide spaces is itself a problem as yet by no means solved.

Before proceeding to study the geology of Equatorial Africa as in any way affording a possible clue to the origin of the halolimnic fauna and especially the gasteropods, which present such a contrast to the average fresh-water molluscs of Tanganyika or of any other African lake, we might consider a possible explanation, which has already been put forward, viz., that some of the halolimnic genera, such as *Paramelania*, for instance, might be related to such a stock as *Pyrgulifera*,* a fossil from fresh-water beds of the Upper Chalk in southern Europe. As far as external appearances go, the halolimnic *Paramelania* resembles the Cretaceous fresh-water *Pyrgulifera* quite as much as it does the Jurassic *Purpurina*, and since *Pyrgulifera* was nearer in time and moreover a fresh-water shell, it might with more probability be regarded as an ancestral form. Too much stress should not be placed on the resemblance of a single genus, but it is a fact of some importance that a fresh-water genus of the Cretaceous period is conchologically as like the old *Purpurina* as any of the Tanganyika shells.

On the possible transference from marine to fresh-water con-

* Figured on p. 343 of the *Tanganyika Problem*, and referred to on p. 335.

ditions.—If we accept, merely for the sake of the argument, the marine origin of the Tanganyika halolimnic gasteropods, and still further if we suppose that they are derived from certain indicated Jurassic forms, it becomes a question when and where the transference from marine to fresh-water conditions was effected; in other words, when and where did their ancestors cease to be marine molluscs and become fresh-water ones. I have already said that it is to the immense Congo basin that we must look for any indications on the subject; but before making any attempt in this direction it may be as well to point out the difficulty in supposing that this transference was effected anywhere in the Tanganyika region itself. If such a transference ever took place we should seek for it rather in some region where Jurassic beds are known to occur, or at least in their neighbourhood, unless we leave everything to mere conjecture. Again the question when, *i.e.* to say, at what geological period, did the transference take place is equally important. The original Jurassic stock of our hypothesis must have existed as Cretaceous molluscs during the Cretaceous period and as Tertiary molluscs during the Tertiary period. It may be argued that these considerations are in favour of an early separation from a marine area, since fresh-water conditions are held to be conservative of form, and consequently the more remote in time the transference took place the less likelihood of change in the morphology of the shells.

Undoubtedly, in the long run, these questions of when and where, which I have put before the members of the Institute, must be determined by geological and above all by palaeontological considerations. The nearest known Jurassic fauna of any importance which has hitherto been described is that of north-west Madagascar distant in an air-line from the south end of Lake Tanganyika about 1,400 miles, and almost on the same parallel of south latitude. The improbability that the halolimnic stock was derived from this source has already been indicated, owing to the physical structure of East Equatorial Africa, which we shall presently proceed to study. It is on the whole a fortunate circumstance for the hypothesis of a Jurassic origin for the Tanganyika stock that this is the case, for in these Jurassic deposits, which would have the advantage of being under the same conditions with respect to latitude and presumably in the same zoological province as the area of Tanganyika in Jurassic times, *there is not a single genus of gasteropods which has any especial resemblance to the halolimnic gasteropods of Tanganyika*. See ante, p. 347.

Jurassic fossils of the Mediterranean basin.—Hence, if we still cling to the notion of a Jurassic origin, we must go further afield and direct our attention to other Jurassic deposits and especially to those of the Mediterranean basin, as being more likely to give us some inkling of a possible derivation in this direction. I have already referred to the very rich deposits of the Lias-Oolite in Sicily, but we may come to Africa itself, where, in the extreme north, marine Jurassic and Cretaceous beds have been fairly well exploited, both in Algeria and Tunisia. Now, as a proof of the apparent poverty of the Jurassic beds in Gasteropoda, I would observe that Coquand* was only able to enumerate one species, although the Cretaceous and Tertiary beds of this region account for over fifty species of Gasteropoda. It may be noted that *Voluta*, *Strombus*, *Fusus* and *Buccinum*, are quoted from beds of Cretaceous age in Algeria, but this Gasteropod fauna in its entirety has nothing in common with the Tanganyika halolimnics beyond a doubtful shell referred to *Trochus*. In Tunisia† the most ancient formations are those of Jurassic age, forming some of the mountain cores such as Zaghuan. In that country the ammonite fauna is characteristic of certain stages of the Jurassic system, but no gasteropods are mentioned. Still following the Mediterranean coast, when we come to Egypt the Jurassics fail us entirely, and beds of Cretaceous age rest directly on the Archæan.‡

It is not necessary to pursue this line of investigation further beyond observing that if there are any stepping stones between the Anglo-Norman basin and Central Africa *quâ* Gasteropods, they remain to be discovered. I will now direct attention to another aspect of the Tanganyika problem, viz., the Geology of Equatorial Africa, more especially in connection with the physical history of the Congo basin.

* *Géologie et Paléontologie de la région sud de la Province de Constantine, Marseilles*, 1862.

† *Expl. de Carte Geol. Provisoire*, par Aubert, circa 1890.

‡ By this name I propose, without prejudice, to indicate the Crystalline complex which is the foundation-stone of the African continent.

PART II.

OUTLINES OF AFRICAN GEOLOGY WITH ESPECIAL REFERENCE
TO THE CENTRAL REGIONS IN WHICH LAKE TANGANYIKA
IS SITUATED.

It need hardly be observed that Africa is an extensive though well-defined continent, and from its size it might be expected to exhibit considerable variety of rock formation. Yet this is by no means the case, since the proportion of crystalline rocks and barren sandstones is so great that its life history has been, for the most part, but obscurely written. If the medals of creation were ever struck here in any considerable quantity they have since been in a great measure destroyed. The absence of fossil evidence is especially noteworthy in the equatorial regions, which form the special ground of our inquiry.

Roughly speaking for geological purposes the whole of Africa might be divided into three divisions of very unequal size.

(1) *The Northern Division*.—This may be considered as part of the Mediterranean basin, and indeed, almost as European for geological and orogenic purposes, always regarding the Atlas range and its dependencies as being under the same tectonic system as the Alps. Although the precise boundaries of this division can scarcely be defined, it is a limited area and by no means deficient in marine fossiliferous rocks. In Part I, under the heading of Algeria and Tunisia, some of the palaeontological features of this division have already been indicated. Marine beds of Mesozoic and Tertiary age constitute the bulk of these rocks. Morocco may be included in this category.

(2) *The Region of the Great Deserts* constitutes the principal part of the second division. Prof. Cornet* tells us that this is characterized by the horizontality of the palaeozoic beds, as though the area had not been one of disturbance for a long period. He also says that there is a great hiatus in the formations of this region, extending in time from the Carboniferous to the Cretaceous.

* "Formations postprimaires du bassin du Congo," *Ann. Soc. Géol. Belge*, vol. 21 (1893-4).

Egypt might be included in this district, where, as in the case of the Nubian sandstone, beds of Cretaceous age rest on the Archæan. Altogether the Cretaceous and Tertiary beds of this region are analogous to those of Syria and of countries still further to the eastward. The southern extension of the great Cretaceous overlap in this area is not exactly known; but De Lapparent* has recently announced the discovery of Eocene fossils on the frontier of Sokoto due west of Lake Tchad. He also announces the discovery of an upper Cretaceous echinoid, believed to be from Belina, which is 300 miles north of the same lake.

The full significance of these discoveries can only be realised by the aid of a map; but among the results thus obtained we find that marine deposits of Mesozoic and Tertiary age, as proved by their fossils, are now known to exist within 14° north of the Equator. Indeed there is no reason why a considerable portion of the basin of Lake Tchad should not be underlain by Cretaceo-Eocene formations, which in all probability extend from the Atlantic coast of Senegal to the crystalline rocks of the Ethiopian Highlands. The effect of this would be that a much larger portion of Northern Africa than hitherto supposed must be included in our second division, though the limits between this and the third, or peninsular division, cannot yet be defined. There is, however, one marked difference between our second and third divisions, which cannot be too soon realised, viz., that in the second division fossiliferous marine beds of Mesozoic and Tertiary age penetrate into the heart of the continent, whereas in the third division such beds occupy but a narrow fringe between the sea and the peninsular massif. Thus, the physical history of the two regions is entirely different.

(3) *Peninsular Africa*.—Constitutes the third division, and this may be divided as follows:—

Section a. The Cape Beds, which have now been studied for a long time, and which it is necessary in some measure to refer to, if we would endeavour to understand the geology of Equatorial Africa. There is a useful summary of these beds in a recent issue of the *Geological Magazine*,† which I condense as follows:—

* *Bull. Soc. Géol. France* (4) III, No. 3, p. 299 (1903).

† December, 1903, p. 569. See also Seward, *op. cit.* November, 1903, who deduces the age from plant evidence.

	<i>Beds.</i>		<i>Age.</i>
	Superficial Deposits	....	Recent, etc.
Coastal	{ Pondoland Series	....	Cretaceous.
	{ Uitenhage Series	....	Wealden.
	{ Stormberg Series	....	Rhætic.
Karoo	{ Beaufort Series	....	Triassic.
	{ Ecca Series	}	Permo-Carboniferous.
	{ Dwyka Series		
	Cape System	....	? Old Palæozoic.
	Pre-Cape Rocks	....	Archæan.

The beds above referred to the Cretaceous and Wealden are simply strips along the coast, and it may be said generally of the principal system, viz., the Karoo, that its fauna and flora are entirely fresh-water or terrestrial. The older beds on which the great Karoo system unconformably rests contain no marine fossils. It is probable that the beds marked as Rhætic were formerly regarded as Triassic.

Section b.—We now come to consider the geological structure of *Equatorial Africa* adjoining the Cape Beds, which lie to the south. With certain exceptions presently to be described, the beds of this region coincide geographically with the Congo basin. Cornet says of this region that it is constituted by depressed massifs, formed of Archæan and Palæozoic beds much folded; these are covered by beds almost horizontal extending over immense distances, consisting of conglomerates, sandstones and clay schists, all utterly unfossiliferous. This is the unpromising region which we have to study with some degree of detail, but before doing so it will be necessary to glance at the history and structure of the peculiar mountain chain, which though it hangs to the eastern side of the continent, is called by Mr. Moore the great Central Range.

The mountain-chain or plateau-range of East Africa.—In the above geological disquisition we must not lose sight of our main object, which is to account, if we can, for the presence of the peculiar halolimnic fauna of Lake Tanganyika. Now this lake, which has a length from north to south of 400 miles, lies at the junction of the Great Central Range with the enormous Congo basin. We shall consider the structure of the Congo basin in some detail presently, but a few words as to the peculiar mountain system with which the lake is connected ought to be useful. If we want to account for anything, we must understand the position on all sides.

This mountain chain is largely volcanic in its composition, and it will be sufficient for our purpose if we take our start from the great volcanic mountain mass of Abyssinia, whose geological

B

features, to a certain extent, resemble those of the peculiar mountain plateau-region which is characteristic of Equatorial East Africa. Isolated volcanoes, now extinct, such as Elgon, Kenya and Kilima-Njaro rise to heights, in the two latter cases, of over 18,000 feet, but the most characteristic feature is the double chain of depressions which contain the numerous longitudinal lakes of Equatorial Africa. This system, which may be said to commence with Lake Rudolf, just south of Abyssinia, bifurcates, the eastern and smaller arm containing such lakes as Baringo (3,200 feet), and Navaisha (6,200 feet), whilst the western, or more important arm, includes the uppermost Nile-valley and such lakes as the Albert Nyanza (2,300 feet), the Albert Edward (3,240 feet), and Kivu (4,900 feet). This latter lake, as Mr. Moore has shown, formerly belonged to the Nile-valley system, but owing to volcanic extravasations the drainage has been reversed and its waters now find their way into Lake Tanganyika (2,700 feet). The two arms of this double series of longitudinal depressions are regarded as to a certain extent coalescing in the great lake of Nyassa (1,500 feet), where the system of these peculiar longitudinal depressions may be said to terminate. The mountain system of East Africa, in another form, is renewed in the Drakensberg, where the surveyors have lately found numerous indications of volcanic action. A sketch-map of the East African Lake-Chain (after Suess), modified from Gregory's *The Great Rift Valley*, is appended. (Fig. 1.)

Between the two arms of the system of longitudinal depressions ("Graben" of Suess) is situated, the wide basin of the Victoria Nyanza (3,900 feet) which has an area in miles of 270×225 —a veritable inland sea. This constitutes a sort of broad and shallow depression in complete contrast to the Graben with their vertical walls and succession of trough faults.

Our brief sketch of the Great Central East African Range would not be complete without allusion to two very remarkable features in connection therewith, which characterize the uppermost Nile-valley system in the neighbourhood of the Lake Albert Edward. The first of these is the still active volcanic range of Mount M'fumbiro which crosses the great western arm of the Graben system at a right angle, and rises to a height of 14,000 feet in Karisimbi (extinct), whilst the rim of the crater of the still active Kirungu-cha-Gongo Mr. Moore found to be 11,350 feet. As he observes, this mass acts like a dam to the original drainage of the Graben. The chief points to note

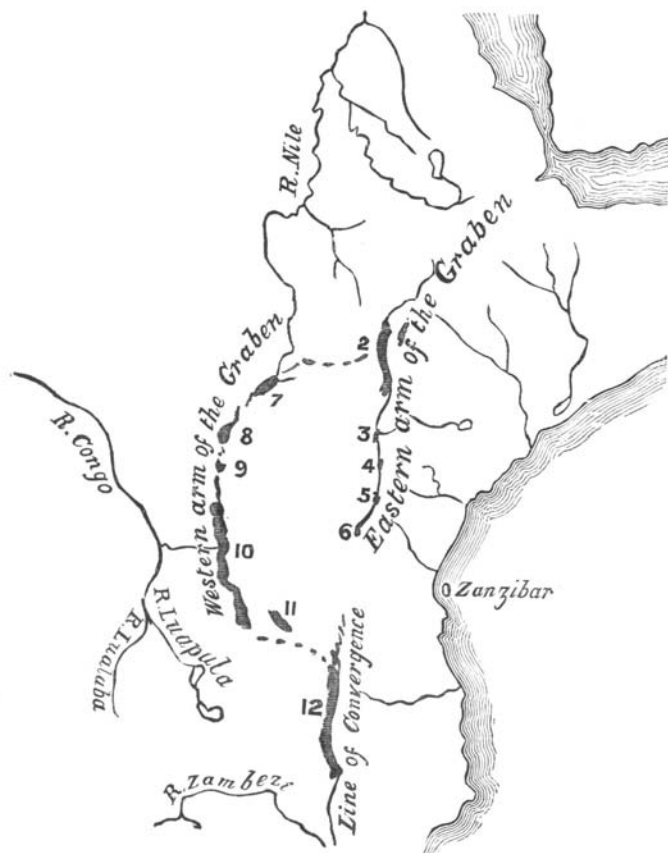


FIG. 1.—PLAN OF THE GRABEN SYSTEM AND ITS RELATION TO THE CONGO BASIN.

Eastern Arm.

1. Lake Stefanie.
2. " Rudolf.
3. " Baringo.
4. " Navaisha.
5. " Natron.
6. " Manyora.

Western Arm.

7. Lake Albert.
8. " Albert Edward.
9. " Kivu.
10. " Tanganyika.
11. " Rukwa.

12. Lake Nyassa.

in this case are: (1) The existence of volcanic action within the containing walls of the great western Graben. (2) The fact that volcanic action is not extinct in this region, though it

B 2

is probably fast dying out. There are yet some traces of volcanic activity in the eastern arm of the Graben, where the mountain, Longonot (9,350 feet), still shows a fresh looking crater and emits steam. The facts in regard to the existence of modern volcanic action in the Graben system is of importance in connection with any attempt to estimate the age of this mountain plateau-system, in which the Graben themselves are situated.

The second feature in connection with the equatorial portion of the Great Central chain is the existence of the short, but lofty Ruwenzori Range, whose southern extremity lies actually on the equator. Whilst the axis of the volcanic chain of Mount M'fumbiro lies at right angles to the northerly trend of the great western Graben, that of the crystalline system of Ruwenzori is approximately parallel to it. "These ranges, which rival the Alps in magnitude and in the sublimity of their scenery, lie along the eastern edge of the depression, and appear, in fact, to stand out into it beyond what was originally its eastern face."* We recognise the importance of the above observation, as it tends to show that this portion of the Graben is older than the Ruwenzori Range itself. The adjacent Victoria Nyanza plateau is mainly composed of schists and gneiss, and this class of rock usually terminates abruptly at the eastern edge of the Graben where the depression ensues. But opposite Ruwenzori, instead of being broken off at the edge of the depression the gneiss and schists are bent and piled upon the steep flanks of the mountains themselves, which in their more central portions are found to consist of massive old amphibolites. These latter are, most probably, the base of the Archæan, as developed throughout the greater part of Equatorial Africa, and these amphibolites seem to have been thrust up through the overlying gneissic and schistose layer.†

Geology of British East Africa.—Having paid some attention to the physical structure of the Central Range with its associated Lake Chains, it would not be amiss just to glance at the geology of the equatorial region of East Africa and its relations to the remarkable system of Graben already partly described. In this respect we cannot do better than follow Gregory in his description of the region between the Indian Ocean and the Victoria Nyanza, which includes the eastern arm of the Graben system. The subjoined section, which lies

* Moore, *The Tanganyika Problem*, p. 94. He gives the altitude of the highest peaks at about 16,500 feet.

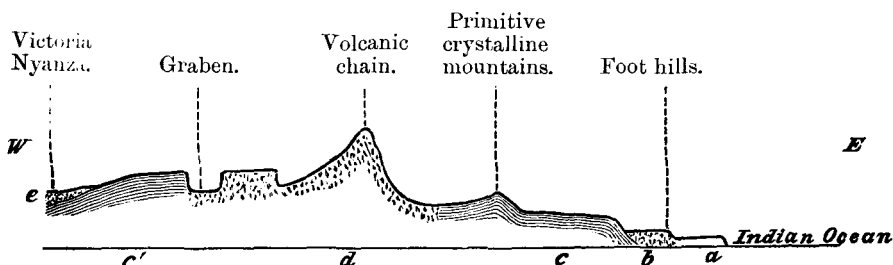
† *Amphibolites* are igneous rocks in which hornblende is a chief constituent; diorite is a common variety.—E. H. (ED.)

almost on the Equator, will serve not only as a description of the immediate region, but may in many respects be regarded as typical of Peninsular Africa, both east, south and west.

In particular the section shows :

- (1) That fossiliferous deposits are a mere coastal fringe, or at least get no further inland than the Foot Hills, and,
- (2) The enormous development of old crystalline and more recent volcanic rocks.

FIG. 2.—SECTION ACROSS BRITISH EAST AFRICA (AFTER GREGORY : " RIFT VALLEY," p. 222.)



GEOLOGICAL SIGNS.

- (a) Coastal deposits : raised coral-reefs and old sea beaches with much wind-borne sand.
- (b) The foot plateau. The seaward portion consists of shales, etc., of middle Jurassic age as proved by their ammonites ; the middle portion of bright coloured sandstones, probably of Triassic age, but without marine fossils ; the western portion of shales of probably Permo-Carboniferous age, with land plants and fresh-water mollusca (*Palaeonodonta*).
- (c) The portion of the Archæan rocks to the eastward of the volcanic region.
- (d) Volcanic region, consisting of plateaux, mountains (Kenya, Kilima Njaro, etc.), and Graben.
- (e') Archæan rocks west of the volcanic region. N.B.—The Archæan system is said to cover something like two-thirds of British East Africa, and there can be little doubt that it underlies the greater part of the rest.
- (e) Lower Palæozoic rocks without fossils on the horizon of the Karagwe series—here and there on the shores of the Victoria Nyanza.

An old crystalline axis is well shown in the above generalized section, and, as we perceive, these crystalline rocks are stated to cover two-thirds of this part of the country. Indeed it has always been an idea of mine that the immense extent of old

crystallines in Peninsular Africa helps us to understand the sandy and unfossiliferous nature of the bulk of its sedimentary rocks. What we now see are merely the eroded stumps of crystalline masses which once towered in the air, but which have been riven for ages by equatorial storms and rains, and their material distributed by torrents, rivers, and backwaters, so as to help to level up the surface. In this particular case the crystalline system has been invaded by an enormous extent of volcanic extravasations, and if we wish to discover the age of the Great East African Central Chain, as it now exists, we must endeavour to ascertain the period during which these phenomena have been in operation. The origin of Lake Tanganyika itself depends upon these considerations. That this period is post-Jurassic, there can be little doubt, for the strip of Jurassic rock near Mombasa is traversed by dykes, which seem to be connected with the general mass of extravasated matter on the central plateau. It is probable, however, that a much later date may be assigned. In this connection I would refer to Dr. Gregory,* who places the first plateau-eruptions in the Cretaceous, probably towards the close of that period, as is the case with the great basaltic outpourings of Western India. From this time up to the Pleistocene there have been, according to this author, a succession of eruptions and coast-movements, and he places the first series of Rift-Valley faults (Graben) in the Upper Eocene and the second series in the Pliocene. These statements are made, principally with reference to the eastern arm of the Graben system, but it would probably apply also to the western arm in which Lake Tanganyika is situated. It is pretty clear, however, that volcanic eruptions have taken place, as we now know, down to the present time, and that earth movements have continued, for some of the fault scarps, Dr. Gregory observes, are so bare and sharp that they must be of very recent date.

Enough has now been said with regard to the anomalous history and condition of the Great East African Central Chain and its double string of lakes of depression. Tanganyika is the largest and most peculiar of all these, and its origin is intimately connected with the above considerations. We may believe that its initiation may have taken place in early Tertiary times, but that both its drainage area and also the great Rift in which it occurs have undergone some modification owing to the instability of the earth's crust in that region.

* *The Great Rift Valley*, p. 235.

Geological structure of the Congo basin.—The above considerations present to us only one phase of Tanganyika's history. If we desire even to try to account for its peculiar fauna we must now turn to another factor in the case, viz., the geological structure of the Congo basin, with which it seems, almost by accident, as it were, to be connected. This is a very large subject, and the region under consideration is quite the converse of the one previously described; for we are about to deal with an immense circular area having only an elevation of from 1,000 to 2,000 feet above sea level, and which, for the most part, seems to have been free from tectonic disturbance. It might be thought there would be immense variety of formations in this region, but if the Belgian and French geologists, whom I shall presently quote, are correct, we have the old story over again:—a rim of crystalline and, possibly, palæozoic rocks, with absolutely unfossiliferous sedimentaries, largely consisting of sandstones, dumped down in the centre.

The best evidence we obtain of the general structure of the Congo basin is derived from the writings of Professor Cornet, of Mons, supplemented for the French Congo by those of Mons. Barrat, a mining engineer, and inspector of public works.* The first mentioned author is a geologist of great experience, and his earliest work in this region (Katanga) relates to the geology of the Uppermost Congo in the basin of the Lualaba, which is almost in touch with Tanganyika itself. Before venturing, however, to deal with this ground, I will bring to your notice Professor Cornet's experiences on the Lower Congo. The railway from Boma to Stanley Pool has materially helped the engineer to obtain a fairly accurate idea of this piece of country. It is true that this railway is only 350 kilomètres (216·35 miles) in length, and that the distance from the outlet of the Lukuga on Lake Tanganyika, measured in a straight line along the sixth parallel of south latitude, is nearly 1,300 miles, yet the section traversed by the railway and prolonged to about the neighbourhood of Bolobo, appears to be the key to

* Cornet. "Terrains anciens du Katanga (expédition de 1891-93)," Liège (1897).

Cornet. "Observations sur la géologie du Congo occidental." *Bull. Soc. Géol. Belg.*, vol. x (1896).

Cornet. "Études sur la géologie du Congo occidental." *Op. cit.*, vol. xi (1897).

Cornet. "Les formations post-primaires du bassin du Congo," *Ann. Soc. Géol. Belg.*, vol. 21 (1893-4).

Barrat. "La géologie du Congo Français." *Ann. des Mines*, Livraison d'avril (1895).

the structure of nearly the whole basin of the Congo. I may be pardoned, therefore, if I dwell upon this section on the Lower Congo in some detail.

The western Congo may, from a geological point of view, be divided into four zones from west to east as follows (see Fig. 3, page 361.)

- I. The Maritime Zone.
- II. The Crystalline Zone.
- III. The Calcareo-schistose Zone.
- IV. Zone of the Sandstones.

I. The Maritime Zone.—This consists of old estuarine deposits, and more particularly of fragments of Tertiary beds, Cretaceous beds, and of continental pre-Cretaceous sandstones. It is interesting to note that the only fossiliferous beds whose age may be known from their contents, constitute a narrow and insignificant fringe on the borders of the Atlantic, just as we have seen to be the case on the east coast of equatorial Africa (see Fig. 2, p. 357). All the other zones are without any definite traces of organisms.

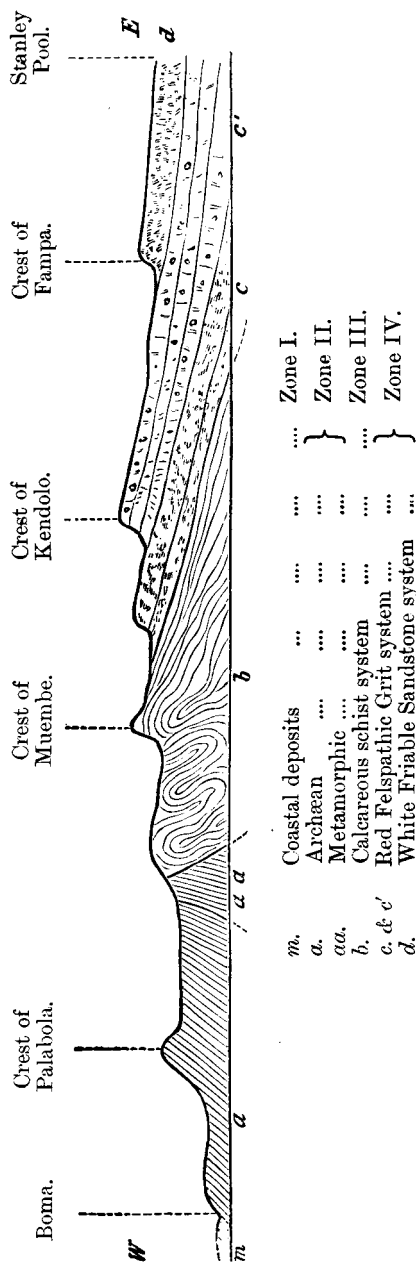
II. The Archæan and metamorphic beds.—The Archæan is well represented on the Lower Congo from the granitoid gneisses of Boma, in the west, to the chlorite and sericite schists of the higher portions. The dip is generally towards the west at variable angles, which are sometimes low. Both north and south of the Congo this zone can be traced for some distance. The so-called metamorphic beds are less crystalline, and in some cases calcareous.

III. The calcareous-schist system.—There is a massive conglomerate at the base, and this is succeeded by schistose argillaceous limestones. The middle member consists largely of marbles, whilst the highest beds are calcareous schists with silicious concretions. The beds of this system exist in a series of synclinal basins indicative of a thrust towards the west, and with a diminution of folding as one advances eastwards, until the beds pass under the felspathic grits of the fourth zone with a slight dip to the eastwards. The age of these beds is uncertain, but it is thought that part of them may represent in time the Devonian of other countries.

Zones II and III represent the rim of the basin in which the nearly horizontal sandstones of the fourth zone were deposited.

Zone IV. Zone of the Sandstones, or beds of the Congo basin proper. These are the beds to which Professor Cornet more

FIG. 3.—DIAGRAMMATIC SECTION ON THE LOWER CONGO BETWEEN THE ATLANTIC COAST (W.) AND STANLEY POOL, ABOUT 1,000 FEET ABOVE THE SEA (E.) (AFTER CORNET).



N.B.—The beds of Zone IV are in complete discordance on the underlying rocks, and constitute the "formations post-primaires" of Prof. Cornet.

particularly alludes in his paper on the "Formations post-primaires." The lowest, or *Red Felspathic Grits*, is divided into two sections by a slight unconformity. It reposes in complete discordance upon the flanks of Zone III. There is a great variety of detrital matter in this formation, including conglomerates, fine grained sandstones and argillaceous schists, but one of its characteristics consists of thick beds of grit largely charged with big grains of altered felspar causing a reddish or brownish tinge. These beds correspond to the "couches de Kundalungu" of the highest Congo (Lualaba), and form part of the margin of Lake Tanganyika, as we shall see presently. On the Lower Congo the Red Felspathic Grit series extended to the westward of its present outcrop, as shown by outliers, possibly as far as the crystalline zone.

The upper portion of Zone IV, *d* of the section, which is strongly in evidence near Stanley Pool, extends up the river as far as Bolobo. It consists of white or yellowish silicious sandstones, very pure, soft and friable under the fingers, forming beds several hundred mètres in thickness and having a wavy and current-bedded stratification. Enormous sarsens attest the former presence of these beds in areas where the softer material has been removed by denudation. The beds of this system, in this region, are nearly flat, or with a slight dip to the eastward. They correspond to the "couches de Lubilache" of the Lualaba district, and may be known as the *White Friable Sandstones*.

It will not be necessary to carry the geological *résumé* of the Lower Congo any further, beyond pointing out one or two matters which may have a bearing in future discussion relative to the fauna of the Middle Congo, and, in consequence, of Lake Tanganyika. In the first place it must be borne in mind that from Stanley Pool to Boma the present river Congo has cut for itself a passage through what may be regarded as the western coastal range in a series of falls and rapids which precludes any present connection with marine conditions. We cannot doubt that during the initiatory stages of this escape from the interior, the waters of the Congo basin selected the most depressed portion of the coastal range, which thus presents an appearance, in section, of less importance than would be the case either to the north or the south of the river's course; also denudation has been active in lowering the rim of the original basin. It may be mentioned in this connection that the coastal range in the north of the French Congo (province) attains elevations of 1,500 mètres in the "Monts de Cristal,"

which are of granite. Secondly, it must be remembered, that, as far as what we may term the solid geology is concerned, the White Friable Sandstone series is the highest in the sequence of the beds which form the vast interior. These are often concealed by horizontal beds of clayey and sandy alluvium (silt), dating from a period when the mean level of the river was higher; also by spreads of what the French geologists call "Laterite." Even these alluvial beds seem devoid of organic remains, except that in one case shells of *Ætheria* are mentioned.*

Having thus briefly considered in some detail the material of which the Congo basin, in a geological sense, is constituted, we are now in a position to glance at the structure and physical history of that immense area, including some attempt to fix the chronology and parallelism of the two great sandstone systems, which probably cover more ground than any other sedimentary beds throughout Africa. Cornet, in speaking of the physiography of the Congo basin, describes it as an immense "vat," whose peripheral margins are always higher than the central region.

The periphery of the Congo basin (Plate I).—The western portion we have already studied in the traverse from Boma to Stanley Pool. Although the topography varies throughout this immense circle, the geological sequence is pretty much what we have seen. Thus, on the southern margin, the watershed between the Congo and the Zambesi, towards the sources of the Lualaba, runs from elevations of 4,000 feet to 5,000 feet. On the south-east the headwaters of the Congo-Luapula proceed from a region of gneiss, mica schists and argillaceous schists with granitic massifs, which extend between lakes Nyassa and Tanganyika. The "ancient rocks" of Katanga, so well described by Cornet, of course form a part of the general periphery in these regions. It would be well to mention here that, although such ancient rocks are, in the flatter parts of the basin, covered

* There is an article by Stainier (*Trans. Inst. Mining Engineers*, vol. 15 (1898) p. 491), in which the author, besides summarizing the results of Cornet and others on the solid geology of the Congo basin, gives a very useful abstract of the *superficial formations* of this immense area. These include (1) Products of the alteration *in situ* of subsoil rocks; (2) Products of decomposition on slopes under the influence of rainfall; (3) Alluvial deposits in watercourses; and (4) Ancient alluvial deposits. It can readily be understood that the solid geology of the Congo basin is largely masked by some one or other of the above conditions, to say nothing of vast districts under water and swamps.

by one or other of the sandstone systems (formations post-primaires), yet the latter have been cut clean through by streams in many places so that the framework and bones of the skeleton are occasionally displayed throughout the vast region under description.

The eastern margin of the periphery calls for especial notice, as Professor Cornet considers Tanganyika to be within the limits of the original basin, since the Red Felspathic Grits extend to the east as well as to the west of the lake. Its eastern affluents descend from a granitic or metamorphic district stretching towards the east and also bordering the lake for a considerable distance. When we come to deal more especially with the geology of the shores of Lake Tanganyika it will be seen that these Red Felspathic Grits, almost horizontal in many places, are occasionally tilted in this region, showing that Tanganyika is within the influence of the disturbances in connection with the Great Central or East African Range, whereas the Congo basin, as a whole, is outside these influences. The south end of the lake is bordered with red and variegated grits belonging to the Red Felspathic series which are horizontal and have been transformed by metamorphism into a kind of quartzite with intercalation of eruptive rocks. At the outflow of the Lukuga are seen grits and red schists (of the Red Felspathic group) which continue for a distance of 120 kilometres westward from Tanganyika. At this point (Wabenza) they are covered by the white friable schists (White Friable Sandstone) of the centre of the basin. This formation also prevails at Nyangwe, but the Red Felspathic Grits reappear at Stanley Falls.

The limits on the north-east of the periphery are constituted by the western lip of the western arm of the Graben, which contains the lakes belonging to the Upper Nile. The region of the sources of the Aruwimi consists of crystalline rocks. On the north gneiss occurs at several points between the basin of the Uellé and the White Nile.

On the north-west there is a sandstone plateau of an altitude of 2,000 to 2,800 feet, which occupies the meeting ground of the Shari, Congo and Nile basins, and falls to the north in a plain some 400 feet lower, watered by the Auk, an eastern branch of the Shari, the principal feeder of Lake Tchad.*

* Chevalier, quoted in the *Journal of the Royal Geographical Society*, vol. 22, p. 569 (November, 1903).

This completes the periphery of the Congo basin as at present constituted.

Suggested correlation of the beds composing the interior of the basin.—Having completed the circuit of the Congo basin, we must next endeavour to ascertain something of the geological history of this vast tract and its constituent elements. The first question we ask ourselves must be, what is the approximate age of these two great interior sandstone formations? Without fossils, terrestrial, fresh-water or marine, to guide us, this can only be done by way of inference and analogy.* Cornet calls them post-primary, *i.e.*, to say, they rest in almost horizontal layers, for the most part, either on crystalline rocks or on old palaeozoic rocks inclined at high angles. This is very much the case with the Karoo beds at the Cape, which are in position analogous to the two sandstone series of the Congo. The Karoo beds fortunately contain a fairly abundant fauna and flora, which is wholly terrestrial and fresh-water. The geological position of the Karoo beds is pretty well known, and I must refer to a previous statement on this subject (see page 353). We are not altogether without links in the chain of evidence.

A paper appeared lately in the *Quarterly Journal of the Geological Society* by Mr. Molyneux† on “The Sedimentary Deposits of Southern Rhodesia,” where a provisional classification of the several formations, down to the Zambesi, was suggested. Beneath a series of sandstones and grits, capped by volcanic rocks, occur some 800 feet of beds containing workable and impure coal and also some recognizable fossils (Matobola beds). The interest of these consists in the fact that scales of the fish *Acrolepis* were recognized, the genus also occurring in the Lower Karoo, and likewise in the so-called “Drummond’s beds” on Lake Nyassa. A very few lamelli-branches were obtained from the Sengwe coal-field and were described by Dr. Hind. These are small, oval, gibbose bivalves belonging to the genus *Palaeomutela*, similar to species from the Permian of the Volga. A few plant remains were collected, and amongst others fronds of the fern-like plant *Glossopteris Browniana*, Brongn, and of some of its varieties. There can be very little doubt, therefore, that the Matobola-beds of Southern Rhodesia may be referred to the terrestrial and fresh-water Lower Gondwana system of Permo-Carboniferous age. The

* This was Prof. Cornet’s view at the time he wrote.

† Vol. 59 (May, 1903) p. 266.

"Drummond's beds" towards the northern end of Lake Nyassa present similar traces of this fauna in association with a series of conglomerates, red grits and shales, and as they are not far from the south-east rim of the Congo basin their evidence is all the more valuable.*

There is good reason, on the whole, for supposing that the Red Felspathic Grits of the Congo basin are the equivalents in time, and to a certain extent in composition, of part of the Karoo system of the Cape. If this view be accepted we might roughly correlate the White Friable Sandstone series with the Upper Karoo which may possibly extend upwards as high as the Rhætic period. It should be distinctly borne in mind that no marine organisms occur in any of these beds referred to the Karoo. Mons. Barrat, in his map of the Congo basin, boldly correlates the whole of the post-primary sandstone systems of that basin with the Karoo, and in a general sense he is probably not far wrong. Cornet himself considers that the "Bassin primitif du Congo," at the period of the horizontal deposits, was separated by a chain of mountains from a region lying towards the south, south-east and east, where the beds of the real Karoo were being deposited.†

It is difficult to conceive the precise physical conditions under which these lifeless masses were accumulated during a period which may be regarded as very early mesozoic (including the Permo-Carboniferous). That the mountainous periphery already described was being ground down by atmospheric causes and its products distributed by some sort of water action throughout the central depressed area seems certain, and it is also highly probable that during the greater part of the time there was no drainage outlet, so that this part of Equatorial Africa became the dumping ground of a mass of mechanical sediments, which had no means of escape by the usual method of rivers flowing towards the ocean. But a time came, perhaps towards the middle of the mesozoic epoch, when deposit ceased to be the order of the day and these interminable sandstones themselves became subject to the laws of

* The Drummond's beds of Nyassa are described as a small system of grits, schists and limestones with fish (*Acrolepis*), molluscs (*Mutela oblonga*) and plant remains. Other localities are quoted where the Red Felspathic Grits contain remains of vegetation, according to the traveller, Thompson.

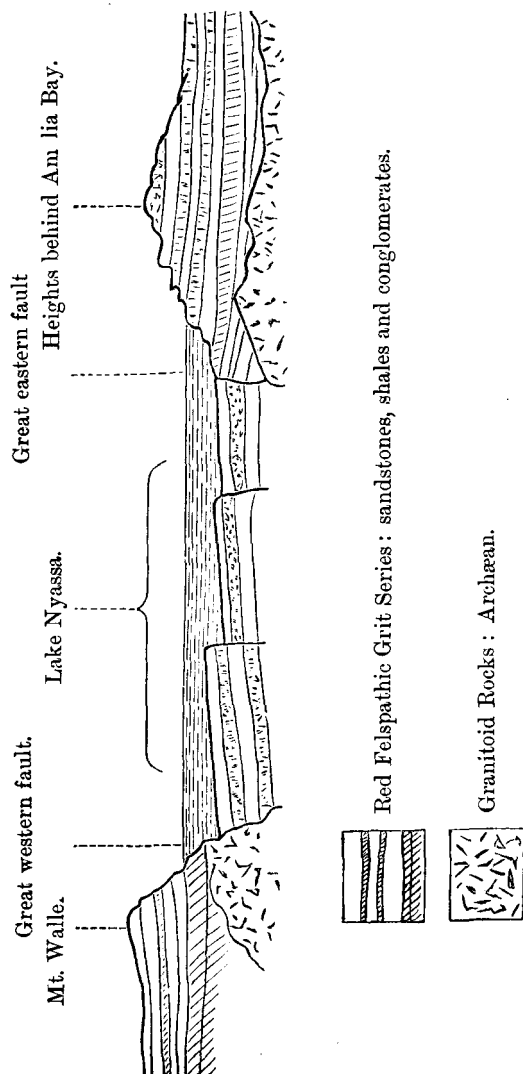
† It is admitted that the Karoo beds of the Cape constitute a somewhat indefinite system, yet within certain limits their horizon may be accepted as fairly well understood.

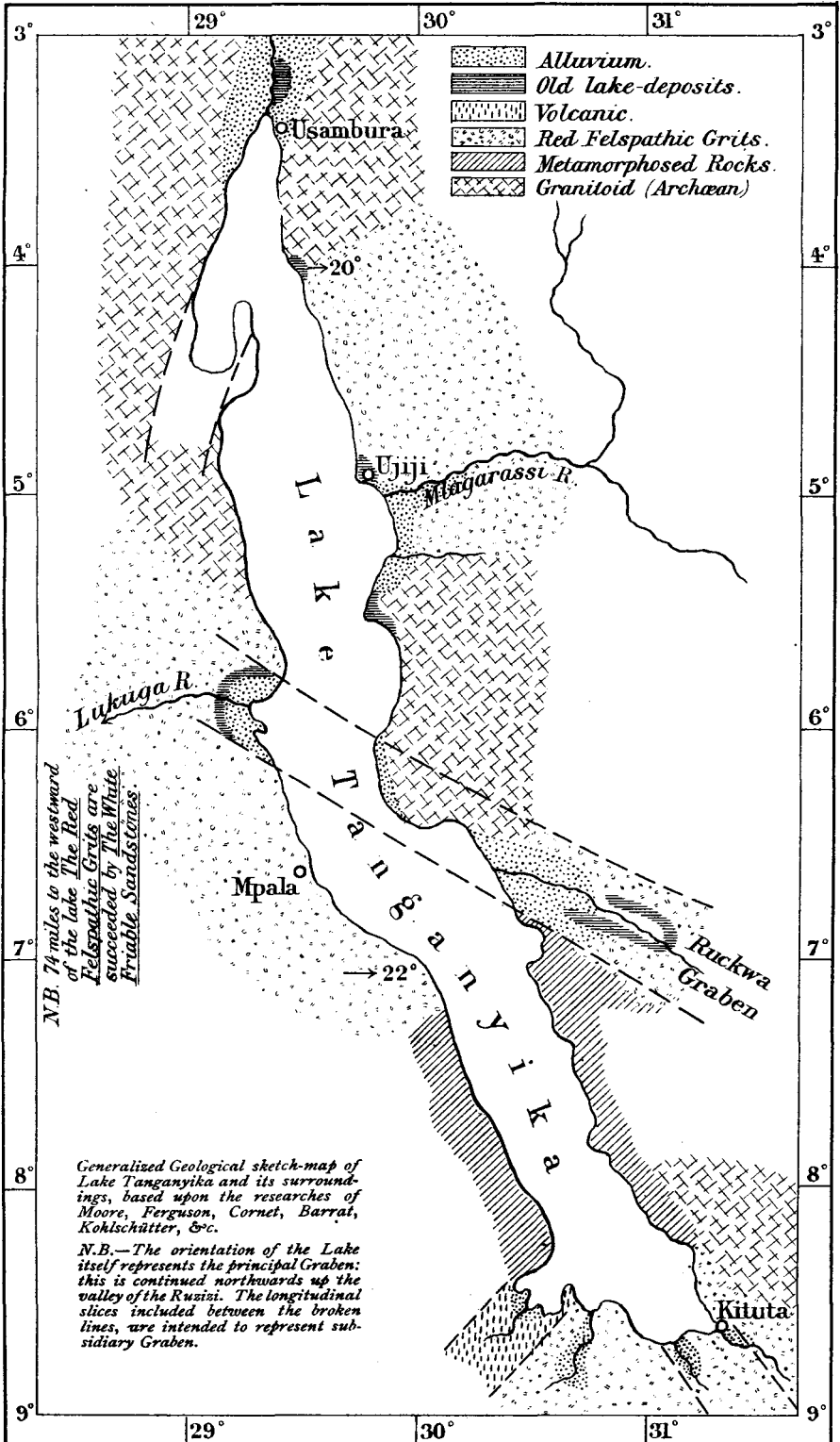
denudation. A new era had arrived, and some faint shadow of modern conditions was inaugurated. Unfortunately, there is no evidence, as far as I can make out at present, of what took place between the close of the White Friable Sandstone period and that of sub-recent and recent deposits. This interval doubtless was, during part of the time, a period of great inland waters, where the basins of the Congo, Shari and White Nile inosculated and where the fauna now existing in Equatorial Africa was to a considerable extent evolved, and the rivers themselves partly marked out. But enough perhaps has been said on this subject, and I must now conclude this geological disquisition with a brief description of the more immediate surroundings of Lake Tanganyika itself, inasmuch as a proper understanding of the peculiar physical features of this lake may help us to consider, if not to explain, the origin of its still more remarkable molluscan fauna.

Structure of a Graben.—Before proceeding to consider the geological features of Lake Tanganyika, I would draw the attention of members to the structure of a Graben as depicted by Mr. Moore, in the case of Lake Nyassa. This traverse which is taken through Mount Waller towards the north end of the lake, shows the relation of the Red Felspathic Grits to the underlying granitoid rocks (Archæan); and it also exhibits the system of trough-faulting which may be taken as one form of the structural arrangement of a Graben.

Geology of Lake Tanganyika.—As regards Tanganyika itself the lake occupies the principal depression in the western arm of the Graben-system of Equatorial Africa, running due north and south for 400 miles, and the present elevation of the surface of the water is stated to be 2,700 feet. There are several affluents, the principal one being the Ruzizi at the head of the lake, whilst there is only one effluent, viz., the Lukuga, which escapes through a chasm in the western walls (? vide Gregory, *The Great Rift Valley*, p. 3), and ultimately joins the Congo drainage system, to which at present it belongs. The discharge of the Lukuga seems to be a precarious one, and it is clear that there have been times when the water does not escape, in which case one would expect an increase in its salinity. Great depths are reached in this lake, and Mr. Moore considers that it is not all of one age, the central portion between Karema and Ujiji being regarded as the oldest. This circumstance is also true of Lake Nyassa, where in some places the bottom is so bare of recent deposit as to suggest that such portions may have been added to that lake

FIG. 4.—STRUCTURE OF A GRABEN.





at a comparatively recent period. Oscillation of the floor and containing walls of both these great Graben lakes is noticeable in places.

In attempting to construct a geological map of Tanganyika I must be guided by Mr. Moore to a certain extent, not forgetting, however, to consult the works of Cornet, Bornhardt, Kohlschütter and other distinguished scientists. If there is obscurity, in the geology of Equatorial Africa, still there is a certain degree of simplicity as far as the composition of the several formations with which we have to deal. Around Tanganyika, though not to the same extent as around Nyassa, the basement granitoid rocks (Archæan) are strongly in evidence. Upon these at the south and south-east end of the lake in complete unconformability reposes the great sandstone and shale formation, which, we have seen, Cornet in his numerous writings on the Congo basin calls the *Red Felspathic Grits*, or "*couches de Kundelungu*" of the Lualaba district, and which constitute the lower division of his "formations post-primaires." Beds of this character also extend to the east as well as the west of the lake, and this part of the area now occupied by Tanganyika must have been within the limits of the original basin of deposition (see *ante*, p. 364). These Red Felspathic Grits, so horizontal for the most part throughout the basin of the Congo, are tilted in portions of the western wall and notably at Mount M'rubi, where they are said to have an inclination to the eastward. As previously observed, this shows that Lake Tanganyika is within the influence of the movements connected with the East African Plateau Range, whereas the bulk of the Congo basin is without the sphere of those influences. At the south end of the lake the Red Felspathic Grits are shown for the most part as horizontal, although, according to Mr. Moore's mapping, much cut up by subsidiary Graben which carry on the principal Graben of Tanganyika in a southerly direction. In one of these subsidiary Graben, towards the south-west, is situated both the true and the salt lake Mwero of the higher Congo, and that perhaps is about as far west as the Graben-system can be traced. In the neighbourhood of Cameron Bay there are considerable indications of volcanic eruptive matter, and, according to Cornet, much of the Red Felspathic Grits have been transformed into quartzites with intercalation of this eruptive material. These most probably are the "metamorphic" beds of Mr. Moore, which seem to occupy both sides of the southern third of the lake.

Towards the northern termination of the series which has

C

been subject to this kind of metamorphism, the great Rukwa Graben strikes the Tanganyika fissure at an acute angle, and it is extremely probable that this longitudinal depression, as pointed out by Mr. Moore, extends across the lake and reappears as the great gap in the western wall through which the drainage of Tanganyika has been effected. Possibly subsequent erosion may have had something to do with the deepening of the primary fissure, which thus becomes a "rift-valley" in the true sense of the term. After passing over modern lake deposits, the Red Felspathic Grits are encountered on the Lukuga as previously stated (p. 364), and extend for a distance of 120 kilometres from Tanganyika, and beyond this point are covered by the *White Friable Sandstones* which constitute the upper member of Cornet's "formations postprimaires."

It seems doubtful whether any fossils occur in connection with the Red Felspathic Grits of Lake Tanganyika. There can be no doubt whatever that the Red Felspathic Grit series of Cornet is the same as the sandstone series of Mt. Waller and Amelia Bay on Lake Nyassa, which is identified by Bornhardt with the Karoo formation, and with which are associated the so-called "Drummond's beds" with their *Glossopteris* flora and fresh-water fauna (see pp. 365 and 366). At more than one spot in the vicinity of the northern end of Lake Nyassa indisputable evidence of coal, fossil plants, shells and fish scales of fresh-water origin have been found. It seems unfortunate that the corresponding beds (*i.e.*, the Red Felspathic Grits) of Tanganyika and the Congo basin seem to be barren in this respect. At least such appears to have been Cornet's opinion, and he accounts, as we have seen, for the barrenness of these beds on the supposition that they were laid down in a basin on the west side of the primary mountain range of what is now East Central Africa.*

* Reymond (*Bull. Soc. Géol. France*, 1885) speaks of certain "schistes fossilifères," collected by Giraud in 1881, at some distance from Mpala on Lake Tanganyika, which were said to contain a *Cyrena* and fish remains (*Lepidosteus*). This alleged discovery on Tanganyika may be the same as that mentioned by Drummond (*Tropical Africa*), where he observed that three days north of Nyassa Giraud found in the schists certain fossils which Bertrand referred to *Lepidosteus* and *Cyrena*. Moreover, Moore considers that "Drummond's beds" occur at two or three localities on or near Tanganyika, but as he mixes these up with modern lake deposits, it is not very easy to get at his meaning, the more so, since no organic remains are mentioned, other than those of the lake itself. On the whole, I conclude with Cornet, that no good evidence of fossils belonging to the Red Felspathic Grit series has hitherto been found in the Congo basin, of which L. Tanganyika at present forms a part.

The next formation in order of time is the volcanic series to which allusion has already been made towards the south-west corner of the lake, and with this may be associated the metamorphosed sandstones, etc., which appear, in fact, to be portions of the Red Felspathic Grits and not "primary metamorphics," such as those described by Cornet in Katanga. These volcanics most probably belong to the graben-system, and must be approximately of the same date as similar volcanics towards the north end of the great Nyassa-graben and elsewhere.

The latest formations in point of time are deposits derived from the lake itself, and these are of especial interest as containing the remains of the existing halolimnic molluscs. It is probable that they may be met with at many places along the shore. Mr. Moore refers especially to the line of coast between Ujiji and Usambora, where layers of modern lake-deposit, somewhat shattered, are found dipping 20° to the east conformably to the sheets of Old Sandstone on which they repose. According to the same author the flat floor of the Ruzizi valley (at the head of the lake) is composed chiefly of modern sandstones and alluvium. Higher up the valley, to about 200 feet above the present surface of the lake, his party kept passing over older and older ground, and the plains thus traversed were found to be intersected by water-courses in some cases to a depth of 90 feet, so that the older stratified materials were exposed. These strata were found to consist of brown and yellow sandstones, having a slight dip to the south, and contained many shell fragments and also some fossilised shells which could be identified as *Neothauma*, *Nassopsis* and *Paramelania*. The age of the deposit is probably Pleistocene, and not only has the water level of the lake fallen, but he thinks that the valley-flat north of Tanganyika has undergone elevation also since those days. It should not be forgotten that Mr. Moore (*Tanganyika Problem*, p. 90) states that the water of the lake is somewhat salt. He observes that it seems to be fresher now than when Livingstone and Stanley examined it. Moreover, as both these explorers aver, there are traditions among the Arabs that, within the recollection of living men, it was a lake which never flowed out at all.

PART III.—CONCLUSIONS.

1. The zoological aspect.
2. The palæontological evidence.
3. The argument from geology.

To a certain extent the probable conclusions have already been indicated in Parts I and II, of this communication, but a brief summary at the final stage may be of use. On the whole we have three main factors to guide us in the investigation, and these we will take in the order above indicated.

The zoological aspect of the question.—This is mainly studied by means of conchological comparison, and it will be seen on referring to Part I, and more particularly to the Appendix, that, in my opinion, the resemblance between the Tanganyika shells and those of our British Inferior Oolite is not sufficiently close to warrant any theory as to the derivation of the former from the latter. But, on the other hand, there is the malacological evidence derived from the study of the anatomy of the existing mollusc, which reveals a peculiar archaic character, and also a singular blending of attributes usually held to be distinct. Such peculiarities, whilst pointing to the exceptional character of this assemblage of gasteropods, fail altogether to establish any connection with the Inferior Oolite of the Anglo-Norman basin. Yet the very existence of a group of halolimnic gasteropods limited to Tanganyika, is in itself a proof that there is something remarkable about these molluscs and such a view is further confirmed by anatomical investigation. Hence these gasteropods may, in some way, have had a remote marine origin, although that need not have been Jurassic.

It has always seemed to me that the most hopeful line of research is to be sought in the waters of the Congo basin, and particularly in Lakes Bangweolo and Mwero. If the halolimnic gasteropods had their origin in the vast inland seas of this immense system, as they existed formerly, there should be some trace of them in the lakes of the Upper Congo. This, Mr. Moore informs us, is unfortunately not the case, although in Lake Mwero a genus closely approaching the *Neothauma* of Lake Tanganyika has been found. I am rather inclined to consider that the zoological evidence points to a local and restricted origin for these Tanganyika shells, and if we accept the theory of their special marine derivation, whether Jurassic or more recent, it must always be with a certain degree of doubt.

The palæontological evidence.—Since the hypothesis of a

Jurassic origin for the Tanganyika shells has been mooted, the Palæontological evidence brought forward in Part I may now be briefly recapitulated. I must confess that the possibility of tracing a connection between the Inferior Oolite fauna of the Anglo-Norman basin and the fauna of Lake Tanganyika had a considerable fascination for me, and I rather hoped that as we approached the Mediterranean basin there might have been some evidence in favour of these views. On the contrary, except in Sicily, no really important gasteropod fauna has been discovered in the intermediate areas, and even in the case of the Sicilian fossils the prevailing assemblage of gasteropods lends but little countenance to any theory of a Jurassic origin for our halolimnic shells.

These considerations were originally based upon a hope that there might be some evidence of a Jurassic derivation by way of the Congo basin, but the more I studied this part of the question the less faith I had in my original expectations. Supposing, as is by no means improbable, that there may have been a communication with Tertiary and even with Mesozoic seas on the northern side of the Congo basin at some period of its history, the misfortune is that we obtain no palæontological evidence in the direction required. If we take North Africa, the Iberian Peninsula, or even the south-west of France, wherever Jurassic deposits are known, they have never yielded a fauna approaching that of the Anglo-Norman basin, and therefore do not help us in the least towards covering the immense distance in space which exists between that classical region and the centre of Equatorial Africa. As regards Jurassic deposits within the limits of the African tropics, such as those of Abyssinia and Madagascar, we have already seen that their fauna, so far as known, has no analogy with the Tanganyika gasteropods. This, however, is a fact of minor importance, since the Madagascar deposits especially occupy a region which there is good reason for believing on geological grounds, has never had any connection with the Congo basin, in which Lake Tanganyika is situated.

The argument from geology.—Since neither the zoological nor the palæontological evidence favours the notion of an Inferior Oolite origin for the halolimnic gasteropods, we must endeavour to ascertain how far the geological history of this part of Equatorial Africa tends to throw any light upon the subject.

In Part II, I have endeavoured to sketch a brief outline of this history, dwelling more especially on the geological structure of the Congo basin, and of that portion of the East

African Plateau-chain which flanks it on the east. The importance of Lake Tanganyika in a physiographic sense is based largely upon the fact that it lies at the junction of these two very different regions, the latter a disturbed, and the former a quiescent one. As constituting a part of the western arm of the Graben-system I am inclined to the belief that it is by no means an ancient feature of the earth's crust. Much depends upon the date assigned to the East African volcanic plateau, which was probably initiated towards the close of the Cretaceous period. The Graben-system is of necessity more recent, and if this system has any connection, as regards time, with the Jordan-valley fissure it must be post-Eocene in date. I think that we may provisionally accept this date for the initiation of the Graben-system, though I should be disposed on other grounds to make it more recent still, bearing in mind that its activities are not yet extinct.

Lake Tanganyika, as Mr. Moore points out, was formed at different times, but since its existence could not precede that of the Graben-system, the oldest date that we can assign to any portion of it is Middle Tertiary. It is not contended, however, that there were no large lacustrine sheets of a different character at the time of its formation in the neighbourhood, and notably in the area now occupied by the eastern portion of the Congo basin. The geological history of this vast territory is unfortunately a blank since the deposition of the "White Friable Sandstones." All we can say is that nothing which could indicate the presence of a Jurassic Sea or even of a Cretaceous Sea has been discovered therein. There can be little doubt that the "Red Felspathic Grits" of Cornet, which underlie the "White Friable Sandstones," may be comprehended under the very wide term of Karoo, which gives us an approximate date. The overlying "White Friable Sandstones" will, therefore, be Mesozoic in age, and probably like the Karoo beds non-marine in origin.

We now come to the consideration of a very interesting question, viz., the connection between Lake Tanganyika, which is a fissure lake, with the wide and quiescent area of the Congo basin. For several years, as you are aware, geographers were in doubt as to whether Lake Tanganyika had an outlet, and when the outflow of the Lukuga was at last established it was thought that the outflow was intermittent. The conditions vary even now, I believe, according to the supply of water in the lake. But what I especially wish to point out is the peculiarity of the Lukuga outlet in a fissure lake surrounded

for the most part by lofty enclosing walls. Was this outflow caused by a cross-fissure (Graben) such as might be produced by the prolongation of the great Rukwa-Graben in the way indicated by Mr. Moore? At any rate these drainage facilities may not always have existed, and in that case Tanganyika during part of its history would be a closed water, and consequently more or less saline. Whether such conditions as these had anything to do either with the origin or conservation of the halolimnic gasteropods I do not venture to say. My endeavour has been to find any geological evidence in favour of the view that they were derived either primarily or secondarily from a Jurassic stock of Inferior Oolite age. It must be confessed that thus far my efforts have been without success. At the same time mere negative evidence must not be accepted as final.

In conclusion, then, since neither the zoological, the palæontological nor the geological evidence affords much support to Mr. Moore's theory, we must regard the Tanganyika problem in its main features as unsolved. In the present state of our knowledge we are not bound to submit an alternative hypothesis. Yet, if we still cling to the notion of a specially marine origin for the halolimnic gasteropods, the most promising quarter for a solution of the riddle is to be sought along the northern margin of the Congo basin, where it adjoins that of the Shari. This opens up the notion of a possible communication through the depression in which Lake Tchad is situated with the undoubted marine deposits of the second geological division of Africa. That the so-called "post-primary" deposits of Equatorial Africa, like their equivalents at the Cape, are, with the exception of coastal strips, mainly of terrestrial and fresh-water origin, I entertain no doubt. The only exception to this rule appears to be a Jurassic formation in Abyssinia known as the Antalo limestone.

It should be distinctly understood that I have not taken up this investigation in a controversial spirit; nor indeed, in the first instance, with a view to controverting the theory of a Jurassic origin for the Tanganyika gasteropods. If, during the course of the inquiry, I have been unable to find evidence in favour of that hypothesis, it has at least been a source of gratification to follow Mr. Moore's lead in his character of explorer and naturalist. In this way both myself and those members of the Victoria Institute who have taken the trouble to follow me must feel indebted to him for having awakened a more than passing interest in one of the many problems of Equatorial Africa.

APPENDIX TO PART I.

NOTES ON THE COMPARISONS BETWEEN THE HALOLIMNIC GASTEROPODS AND CERTAIN FOSSILS FROM THE INFERIOR OOLITE—TOGETHER WITH AN ABSTRACT OF MR. MOORE'S STATEMENTS REGARDING THE MOLLUSCA OF TANGANYIKA GENERALLY.

* Forty-six species of mollusca are enumerated (*The Tanganyika Problem*, p. 138), consisting entirely of Gasteropods and Lamellibranchs, the former preponderating. Of the latter are a number of distinct specific forms supposed to be related to *Unio*. Many of the Gasteropods belong to normal genera, such as *Limnæa* (four species), *Isidora* (two), *Phyopsis* (one), *Planorbis* (three), *Ampullaria* (two), *Vivipara* (one), *Cleopatra* (one), *Melania* (three). There is also the very fine *Vivipara*-like genus, *Neothauma*, Smith, which cannot in any sense be regarded as halolimnic. Mr. Moore further observes that the normal fresh-water molluscs found in Tanganyika are specifically distinct from the representatives of the same genera occurring in the neighbouring lakes. Excluding *Neothauma* there are fourteen Gasteropodean types (p. 218) judged by their conchological characters, generically distinct, as follows, viz. :—

<i>Typhobia.</i>	<i>Spekia.</i>
<i>Bathanalia.</i>	<i>Nassopsis.</i>
<i>Limnotrochus.</i>	<i>Syrnolopsis.</i>
<i>Chytra.</i>	<i>Stanleya.</i>
<i>Paramelania.</i>	<i>Reymondia.</i>
<i>Bythoceras.</i>	<i>Horea.</i>
<i>Tanganyicia.</i>	<i>Ponsonbya.</i>

Out of these the following are regarded as specially representing the halolimnic molluscs, and are classified in six groups, viz. :—

Typhobia and *Bathanalia*, *Tanganyicia*, *Limnotrochus* and *Chytra*, *Spekia*, *Paramelania* and *Bythoceras*, *Nassopsis*.

It is more especially the above forms which are regarded as homœomorphic with certain fossils, chiefly of the Inferior Oolite, and this resemblance has impressed Mr. Moore so strongly, that he is disposed to consider these groups as the partially modified descendants of the old Jurassic molluscs.

As most of these comparisons were made with fossils in my own collection, I have endeavoured, in those cases where it has been possible to procure the particular Tanganyika shells, to check the resulting determinations, of course on conchological lines solely.

1. *Melania admirabilis*, Smith, with *Cerithium subscalariforme*, D'Orbigny.

N.B.—These shells are not referred to in the above list. On pp. 219 and 353 of the *Tanganyika Problem* are back and front views of the

* It is probable that this is not an absolutely full list.

Melania admirabilis of Lake Tanganyika—at least, I suppose that both of these cuts are intended for the Tanganyika shell, and not for the Jurassic fossil. The likeness is by implication only, for on referring to page 273 for the affinities of *Melania admirabilis* I find no recognizable account of that species. It is true that on page 269, the author makes a general attack upon the genus *Melania*; but this is rather with a view of criticising the suggested relationship of *Typhobia* to *Melanopsis*.

The shape and ornamentation of *Melania admirabilis* (judging from the figures) and *Cerithium subscalariforme* are singularly identical. There is some difference in the apertures, for in *C. subscalariforme* there is a well-formed anterior spout slightly reflexed. Not having any specimen of *M. admirabilis* in my possession, I cannot pursue the comparison any further.

2. *Typhobia horei*, Smith, with the genus *Purpuroidea*, Morris and Lycett.

Mr. Moore in this case does not institute any close comparison, but rather suggests (p. 350) that *Typhobia* is matched by the Oolitic fossil genus, *Purpuroidea*, "from which it is difficult, if not impossible, on conchological grounds, to distinguish it." I select *Purpuroidea Morrisii*, Buvignier, a characteristic Great Oolite fossil, to exemplify the genus.

Here the ornamentation and general strombiform character of the shell in each case is strikingly apparent. On comparing the apertures we find that, instead of the short notch of *Purpuroidea*, the inner lip of *Typhobia* is produced anteaally into a narrow and reflexed spout. In other respects both the outer and inner lip in *Typhobia* and *Purpuroidea* greatly resemble each other and equally differ from *Strombus*. Whilst recognising a considerable degree of homœomorphy between the two shells from Tanganyika and Minchinhampton respectively, a comparison of the shell substance seems to suggest important differences. So far as we are able to judge from the usual calcite replacement of the fossil shell, one would say that *Purpuroidea* had a thick and heavy shell. On the other hand *Typhobia* has a very thin and fragile shell, and, despite its identification as a halolimnic shell, has all the appearances of a fresh-water genus—so much so, indeed, that its affinities with *Melania* have been suspected by some, though this would seem to be negated by internal characters. As regards the history and distribution of *Purpuroidea*, the genus makes a doubtful appearance in the Inferior Oolite of the east of England; it is fairly abundant in limited districts of the Great Oolite and is last seen, so far as England is concerned, in the Corallian of Yorkshire. It would seem also to be fairly abundant in the Corallian beds described by Buvignier. It does not occur on a higher horizon in this part of Europe.

3. *Bathanalia howesi*, Smith, with *Amberleya orbignyana*, Hudl.

Bathanalia is figured on pp. 227 and 348. Of this peculiar genus Moore says (p. 228) that it is an inhabitant of deep water throughout

the southern third of the lake, and he considers that, in conchological characters, it is identical with several marine Jurassic fossils, described under *Amberleya*. He further remarks that except for its widely different shell, *Bathanalia* is structurally identical with *Typhobia*. Referring to the diagnosis of *Amberleya*, quoted in p. 346, Moore says that this would absolutely answer for *Bathanalia*. According to his view the thin shell, the absence of all trace of epidermis, and the character of the whorls, as well as the sculpture and character of the mouth, are all essentially the same in *Bathanalia* as they are in *Amberleya*.

Judging from figures only, this is the most striking of all the resemblances. I gather, however, that there are some differences in the aperture.

On p. 348, Moore has figured the back only of my specimen of *Amberleya orbignyana*. The right hand upper figure on this page is intended for an *Amberleya*, which I do not quite recognise. The two lower figures represent *Bathanalia*, back and front. It is unfortunate that no good front aspect of *Amberleya* is presented to the reader, for if the aperture in *Bathanalia* is correctly drawn, it does not possess the straight pillar lip, coming forwards almost to a point, which is so characteristic of *Amberleya*. In all other respects the resemblance is most striking, even to the angular outline of the outer lip, which in *Bathanalia* is prolonged into a short process. It should be observed, however, that there is somewhat of an umbilical opening in *Bathanalia*, whereas the shell of *Amberleya* is entirely closed.

Amberleya (including *Eucyclus*, which latter, if not a synonym, has a close relationship) is eminently characteristic of the Lias. It comes up from the Lower Lias, and culminates in the Inferior Oolite, especially in beds having a Cephalopod facies, as in the Anglo-Norman basin. Occurs also in the Great Oolite, and seems to have left this country with bed of Corallian age.*

4. *Limnotrochus thompsoni*, Smith, with *Littorina sulcata*, Hebert and Deslongchamps.

See pp. 233 and 349. It is also compared with *L. dorsetensis*, Hudl. In the possession of a black epidermis and in its general aspect *Limnotrochus thompsoni* has a certain fresh-water character. The aperture, however, is more like that of *Littorina* than of *Trochus*. The trochiform outline of the shell and the ornamentation, especially the

* Since writing the above, I have had an opportunity of inspecting a specimen of *Bathanalia* through the courtesy of Mr. Da Costa. I am more than ever impressed with the extraordinary resemblance of the spire to that of *Amberleya pagoda*, but the character of the mouth is so very different, that I conclude the resemblance of the spire to be fortuitous.

strongly bicarinate body whorl, have a singular resemblance to *L. sulcata*, H. and D. The aperture, however, presents considerable differences, and in this respect *Limnotrochus thompsoni* more nearly approaches some of the many varieties of "*Littorina*" *dorsetensis*, the chief difference being that in the latter, the umbilicus is closed and the aperture is not free as in the former case. Nevertheless, the general resemblance is sufficiently striking.

5. *Chytra* (*Limnotrochus*) *kirkii*, Smith, with *Onustus ornatissimus* D'Orbigny.

See pp. 229 and 350. Originally the empty shell had been described and figured by Mr. Smith (*Proc. Zool. Soc.* 1881), who classed it under *Limnotrochus*. Mr. Moore has founded for this species the genus, *Chytra*, and further observes that the shell of *Chytra kirkii* is remarkably solid, resembling both that of *Solarium* and *Zenophora* (*Onustus*).

The resemblance of *Chytra* to the Jurassic species referred to *Onustus* is very slight indeed, beyond the general pyramidal shape of the shell. One of the leading characteristics of the Jurassic *Onustus* is the imbricate overlapping of one whorl over the next one, and this feature is equally seen in the *Onustus pyramidatus*, Phillips, as in *Onustus ornatissimus* D'Orbigny. There is no trace of this kind of overlapping in *Chytra*, which, to my notion, has more the character of *Solarium*. The basal characters in *Chytra* are also different to those in the Jurassic species of *Onustus*.

Hence I fail to trace any marked resemblance between *Chytra* and *Onustus*. Nevertheless *Chytra* is perhaps the most thoroughly marine in aspect of all the halolimnic series, the shell being thick and more or less free from epidermis. Indeed, most conchologists, if they did not know its habitat, would hardly suspect that it was anything more than a somewhat aberrant *Solarium*.

6. *Paramelania damoni*, Smith, with *Purpurina bellona*, D'Orbigny.

See pp. 245 and 345, for figures. There are three species of *Paramelania* mentioned by Moore (index, p. 366) viz., *P. crassigranulata*, Smith, *P. crassilabris*, von Martens, and *P. damoni*. Other species also have been described by Bourguignat, some of which possibly belong to *Nassopsis*. The species of *Paramelania* selected by Moore for comparison with the Jurassic *Purpurina* is *Paramelania damoni*, of which unfortunately I do not possess a specimen, and must therefore rely solely on Moore's figures, pp. 245 and 345. The comparative figures are to be found on p. 345. The particular *Purpurina* there drawn is *P. aspera*, Hudl. from the *Concavus*-beds of Bradford-Abbas. This is a very rugose form of *Purpurina*, and its resemblance to *Paramelania damoni* (judging from the figure) is very striking; only that in *P. aspera* and indeed in *Purpurina* generally, the anterior notch or channel is more in evidence, and also more reflexed than in the majority of specimens of

Paramelania. In this respect the regulation *Purpurina bellona* (which occurs on a higher horizon than *P. aspera*) more resembles the average *Paramelania*s of Tanganyika. It should be remarked also that most species of *Paramelania* have a considerable amount of brown scaly or epidermal matter, and are generally thick and nassoid or purpureoid in the texture of the shell. Reference is made to the conchological similarity of *Pyrgulifera*, a genus of fresh-water shells (p. 343) of the Upper Chalk, to *Paramelania*, and this casual identification opens up several interesting questions.

7. *Nassopsis nassa*, Smith,* with *Purpurina inflata* (? auctor).

See pp. 250 and 347. During life this mollusc, we are told, inhabits the surface rocks of Tanganyika and its shells are always richly encrusted with the green algæ which clothe the rocks for a considerable depth. It is sluggish and appears to browse within a very limited area, like the *Patellas* of the Ocean beach.

As regards the Jurassic fossil figured for comparison (upper figures, p. 347) under the name of *Purpurina inflata*, I should point out that this specimen is not *Purpurina inflata*, Tawney, but a peculiar unnamed form which was figured in Plate I of the "Jurassic Gasteropoda." The true *P. inflata* has a very different figure and ornamentation, but possesses a rounded and almost unchannelled aperture, having in fact the least indented mouth of all the *Purpurina*æ.

The real value of these comparisons is an unknown quantity, but the conchological resemblance of both *Paramelania* and *Nassopsis* to certain named and unnamed forms of *Purpurina* is clearly pointed out by Mr. Moore, and admitted, as I understand, by Mr. Edgar Smith. Such resemblances are interesting, but if *Paramelania* and *Nassopsis* are really different genera, as their internal structure would imply, one learns two things from this fact: (1) that the outward form of the shell is not always indicative of the character of the animal within, and (2) that two different genera of existing molluscs are compared with the one Jurassic genus, *Purpurina*.

It may be mentioned here that the genus *Purpurina* was somewhat loosely constituted by D'Orbigny, and was more carefully reconstituted by Piette and Deslongchamps, who regarded it as having relations on the one side with *Turbo* and on the other with *Cerithium* and *Purpura*, Fischer places *Purpurina* among the Littorinidæ, but its real family relationship is by no means clear. In the Jurassics of this country *Purpurina* first makes its appearance in the Marlstone (Middle Lias), culminates in the Inferior Oolite, is rare in the Great Oolite, and dies out

* I possess a specimen supplied by Sowerby and Fulton, marked "*Paramelania coronata*," Bourguignat; which greatly resembles the figures of *Nassopsis nassa*.

in the Callovian of Yorkshire. It is also represented in the Callovian of Montreuil Bellay, where a gasteropod fauna, greatly resembling that of the Inferior Oolite of the Anglo-Norman basin, is found to occur.

8. *Bythoceras*, Moore.

See pp. 238 and 242. There are two species figured, but, so far as I know, no special comparison with Jurassic forms is invited.

9. *Tanganyicia*, Cross.

See p. 246, *T. rufofilosa*. In this case also, no special comparison with Jurassic forms is instituted, but its general resemblance to *Natica* is pointed out. The fine spiral coloured lines are characteristic of this very pretty little shell, which though naticoid in its outline is certainly different as regards shell-substance to the regulation *Natica*. It is said to be a littoral form and occurs in abundance.

10. *Spekia zonata*, Cross or Smith, with the Jurassic genus, *Neridomus* M. and L.

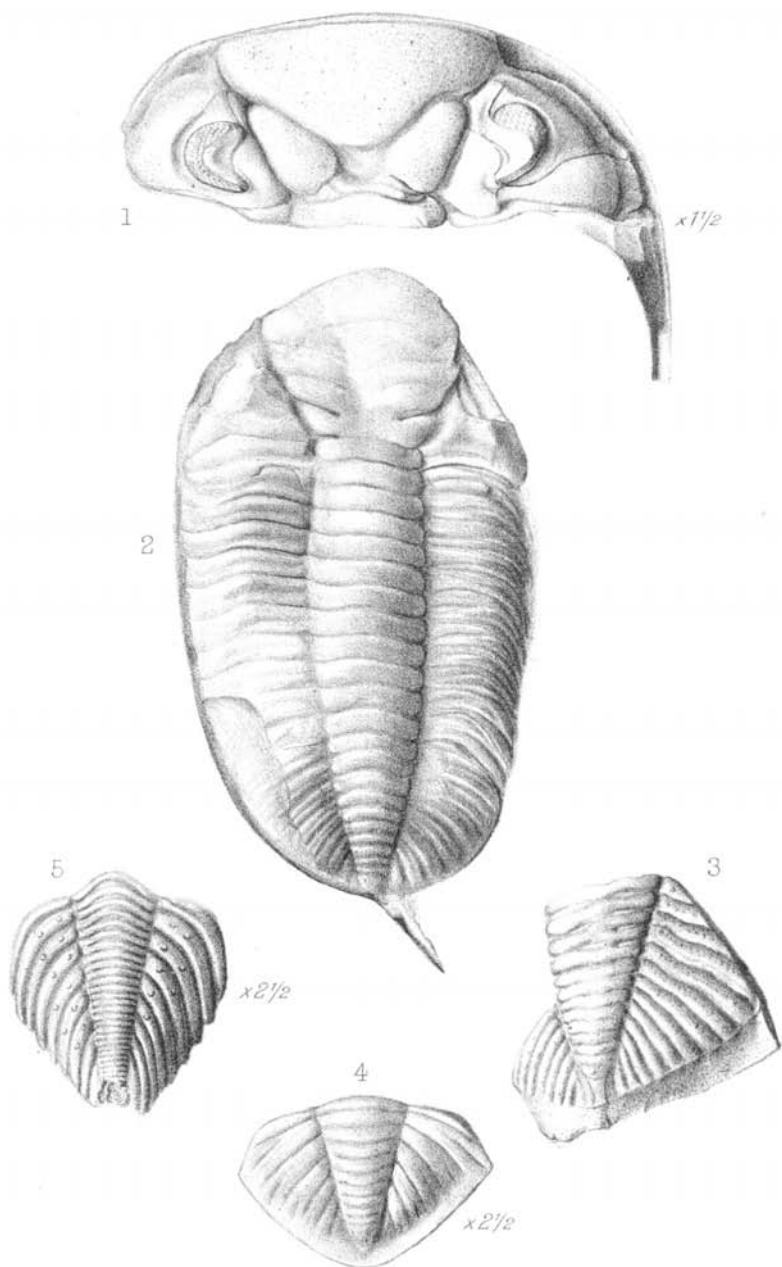
See pp. 256 and 351. On p. 257, Moore remarks on its naticoid appearance, and considers it so "completely similar to that of numerous fossil naticoid forms that, had it appeared fossilized instead of having been found living in a great fresh-water lake, there is not the slightest doubt that it would have been placed in one of the numerous fossil genera which are supposed to group themselves about the living Naticas." Yet on p. 349 (the figures are on p. 351) he says: "Again we find that the shells of the Tanganyika genus, *Spekia*, are practically indistinguishable from the fossil remains of the marine Jurassic genus, *Neridomus*."

In this latter conclusion he is partly correct, for there is no doubt that the affinities of *Spekia* are with the Nerites rather than with the Naticas. *Spekia* is neritoid, not naticoid, but I fail to trace any especial resemblance to *Neridomus*. If the reader turns to the illustrations on p. 351, he will perceive that the two representations of *Spekia* are back views, whereas the two intended to represent *Neridomus* are front views, nor does the author assist the comparison in the text. But if we take a typical Jurassic *Neridomus* such as *N. Hemispherica* from the Great Oolite of Minchinhampton, which may be regarded as the type on which *Neridomus* was founded, we at once find that the columellar region is convex and the shell imperforate, whereas in *Spekia zonata* the columellar region is extremely concave, and in some specimens a peculiar umbilical slit is noticeable. Hence, beyond the fact that both *Spekia* and *Neridomus* belong to the Neritidæ there is very little resemblance so far as the anterior aspect is concerned. It may be remarked, in conclusion, that *Spekia zonata* is related to *Neritina* rather than to *Nerita*. There is nothing naticoid about it, and moreover its thick epidermis and general aspect are highly suggestive of fresh-water conditions, although its shape may be somewhat unusual.

Of the remaining genera of Gasteropods enumerated, none are especially correlated with Jurassic forms, although they are regarded as belonging to the halolimnic group. *Syrnolopsis* is a genus of small elongate shells represented by two species, and there is stated to be an almost exact conchological identity (p. 219) between these shells and the marine genus *Syrnola*. It is not necessary here to comment on all the remaining halolimnic genera, consisting mostly of small forms, but I would point out certain conclusions with reference to some of them, e.g., *Reymondia*, Smith. There are several species, mostly small, but *R. horei*, Smith, is the most conspicuous form, and may be taken as the type. I mention the circumstance because of the very considerable conchological resemblance between this very smooth shell and some of the Jurassic species such as "*Phasianella*" *elegans*, M. and L., and other sub-elongate forms. This identification seems to have escaped Mr. Moore. I don't attach any importance to it, since neither *Reymondia horei* nor "*Phasianella*" *elegans* have any special features of ornamentation like *Amberleya* and *Purpurina*. There is also another case of mock resemblance, where *Horea ponsorbyi*, Smith, presumably a Prosobranch, bears a strong likeness to some of the striated *Actæoninae* of Jurassic age; whilst the remarkably straight columellar lip of *Horea* reminds one of *Orthostoma*, which is, I believe, a synonym of D'Orbigny's genus, *Actæonina*.

Not the least interesting of the Tanganyika molluscs is the handsome viviparoid shell, *Neothauma*, whose varieties are figured on p. 261. This of course is a thoroughly fresh-water genus, and has no connection with the halolimnic fauna beyond sharing the hospitality of the same lake. One of the most remarkable characteristics of *Neothauma* is the extraordinary difference, judging from the figures, between shells from the south of the lake, and those from the middle and the north. If the internal structure is the same in all three, we have again an instance of the difficulty of recognizing an animal by means of its shell even in living creatures. Here again is a singular instance of mock resemblance to a Jurassic species, since the strap-like or bicarinate variety of *Neothauma* would also do for the figure of *Cloughtonia cincta*, Phillips, a well known fossil of the Inferior Oolite of Yorkshire and the East Midlands.

Postscript. This appendix was written before I had the advantage of hearing Mr. Edgar Smith's presidential address to the Malacological Society, delivered in February last. It was highly satisfactory to find that the chief conchological authority in this country had arrived at pretty much the same conclusions as myself, with regard to the presumed connection between the halolimnic gasteropods of Tanganyika and certain shells of the Inferior Oolite.



G.M.Woodward del. et lith.

West. Newman imp. London.

Phacops and Encrinurus.