## DISCUSSIONS AND COMMUNICATIONS.

### *THE CONGO BASIN IN ITS RELATION TO THE REST OF AFRICA.*

South of the great Sahara, geological Africa is the oddity among continents, being a "shield" of ancient formations, overlain by non-marine strata recording extremes of climate and widespread peneplanations, and including inner, shore-line, marine remnants of an eastern and a southern geosyncline. Through economic work carried on since 1919, Dr. A. C. Veatch has become deeply interested in the geology of Equatorial Africa, and he has recently brought together in a very interesting way all that is set down in the widely scattered literature, and interpreted it from his own wide field experience, with the result that "Darkest Africa" is now seen in the clear light of South African geology. The memoir[1] is a description and discussion of the known stratigraphy, physiography, and paleophysiography of the vast Congo Basin, and is well illustrated by geologic maps, diagrams, and views. His geologic maps should be studied in connection with the general one of Africa presented by F. Dixey in "A Provisional Correlation of the Karroo North of the Zambezi" (Compte Rendu, Internat. Geol. Cong., XVth Session, South Africa, 1929, vol. 2, p. 160, 1930).

Briefly, the historical geology of the Congo Basin is as follows:

Deposition of Pleistocene and Recent valley and terrace gravels, with human artifacts of Riss and Würm times.

Very late Pliocene or early Pleistocene peneplanation.

Deposition of late Pliocene or early Pleistocene plateau sands and gravels.

Miocene diastrophism. "The present Congo hydrographic basin is entirely post-Miocene and owes its origin to the uplift and warping of the Miocene Peneplain" (p. 161).

Mid-Miocene peneplanation. This planation began in late Cretaceous time and continued until the middle Miocene, reducing the continent to near sea level.

Deposition of Oligocene local gravels and sands.

Marine Cretaceous (Aptian) marginal overlap of the Atlantic Ocean.

Early Cretaceous peneplanation—"a very perfectly graded stage . . . much of Africa was a plain essentially at sea level" (p. 144).

Deposition of Upper Triassic (Rhaetic) Lubilash formation (top of Karroo series). These are non-marine strata variable in thickness between 450 and 670 meters, derived from higher land to the west. They have rare *Estheria*, *Estheriella*, and fish remains,

[1] Veatch, A. C.: Evolution of the Congo Basin. Geol. Soc. America, Memoir 3, 183 pages, 1935.

suggesting those in the Stormberg beds (Cave sandstone) of South Africa. The Lubilash beds "were formed by stream and wind action, for the most part, on a semi-arid land surface and, to a lesser degree, in more or less temporary dry-climate lakes" (p. 163). The Lubilash gravels are diamond-bearing.

Erosion interval.

Deposition of Lower Triassic Stanleyville beds. These beds are of local occurrence. Veatch correlates the Stanleyville with the late Middle and early Upper Beaufort of South Africa. The Stanleyville beds are essentially deposits of local lake basins, with a thickness varying between 10 and 200 meters. They have zones of oil shales, some of them a meter thick, with fish remains (*Lepidotus, Peltopleurus, Pholidophorus,* and *Colobodus*), ostracods, and phyllopods (*Estheriella, Darwinula, Metacypris,* and *Estheria*). "Stanleyville time was initiated by local faulting and disturbances which created a depression or depressions . . . toward the close of the Middle Beaufort and/or early Upper Beaufort time" (pp. 135-136).

Latest Permian diastrophism and elevation of the Cape Mountains of South Africa. Following the deposition of the Permian Upper Lukuga beds, the "Congo Basin" was uplifted, "with associated faulting and folding, which resulted in the general absence of the Middle and Upper Beaufort (Lower and Middle Triassic) in Africa north of about the 26th Parallel, except near the present East Coast. During the early Triassic erosion period all the Lower Beaufort, Ecca, and Dwyka beds (that is, the Upper, Middle, and Lower Lukuga of the Congo) were removed by erosion, except where they had been infaulted or infolded." The Stanleyville beds were formed in "local fault basins, which may appropriately be called early rift basins" (p. 163).

Deposition of Late Permian Lukuga beds, 120-390 meters thick, and including the coal field of Greinerville. These strata contain the plants *Cardiocarpus, Sphenophyllum* (akin to *S. thoni minor*), *Phyllotheca,* and *Vertebraria.* On the Lukuga River occur *Glossopteris indica, Noeggerathiopsis,* and *Phyllotheca.* Veatch correlates the Lower and Middle Lukuga with the Ecca formation of South Africa. Above the Lukuga lie red sandstones 400 meters thick which are regarded as of Lower Stormberg age.

The Lukuga is divided as follows: Upper Lukuga red shales, 100 meters, with *Glossopteris browniana indica* and *Nummulospermum,* correlated with the Lower Beaufort. Middle Lukuga coarse sandstone and shale, with the main coal seams (up to 2 meters thick), 34-170 meters; near the top occur *Noeggerathiopsis* cf. *N. hislopi, Phyllotheca zeilleri,* and *Glossopteris browniana indica.* The coal beds have *Vertebraria* and *Schizoneura.* At Kongolo occur the additional plants, *Gangamopteris, Cyclodendron matthieui, Strobilites,* etc. Lower Lukuga (= middle and late

Dwyka of South Africa), including black shales, 50-120 meters, with *Glossopteris* and *Cyclodendron leslii*, and basal conglomerates and sandstone (= tillites), ranging in thickness up to 300 meters. At Greinerville the tillite rests "on a striated floor on the surface of the pre-Cambrian rocks" (p. 95).

In the Lower Lukuga beds of the Walikale region, northwest of Lake Kivu, Renier identifies the following Permian plants: *Gangamopteris* (common, including *G. cyclopteroides* and var. *attenuata*), seeds of *Samaropsis*, *Cardiocarpus*, and *Nummulospermum*; also *Voltzia* and *Noeggerathiopsis hislopi*. *Glossopteris* was not collected here, hence this is one of the earliest of the known Permian florules (p. 124).

A very peculiar phenomenon of the Karroo formations of the Congo Basin is that no reptilian remains have as yet been reported from them, although these are common fossils in the Ecca and Beaufort series of South Africa. This is explained in part by the absence of much of the Beaufort strata in the Congo Basin, but the thick and widespread Upper Triassic Lubilash series is also without reptilian remains. Can their absence be due to poor collecting? Hardly. Reptile remains would be far more reliable in chronology than the fishes, phyllopods, and ostracods which have been recovered.

Pre-Cambrian crystallines and metamorphics. Over these lie the unmetamorphosed late Proterozoic Kundelungu shales and red feldspathic sandstones, with tillites at the base 100-600 meters thick. Subsequent to Kundelungu time, these ancient basement rocks were intensely folded by the Katanga orogeny, a mountain making that dates back 600 million years (p. 42).

"This late pre-Cambrian glaciation—represented in Africa by the Griquatown-Pretoria-Kundelungu tillites, by the tillite found by Schellinck at the base of the Kundelungu along the Ituri to the north of Avakubi and Pence, approximately in Latitude 1°20′ North, Longitude 28° East, by the tillite recognized by Delhaye and Sluys at the base of the schisto-calcaire in the Congo Gorge, by the striated boulders found in these beds by Canuet in northern Angola, and by the youngest of the several pre-Cambrian tillites found in South West Africa—had a known range in Africa, from Latitude 30° South to beyond Latitude 1° North and from Longitude 14° West to 28° West." This glaciation in the region of the Belgian Congo "came from the south, thus duplicating approximately, both in extent and in direction of ice movement, the later Dwyka glaciation. One finds in the geologic history of Africa recurrent cycles reproducing, again and again in essentially the same areas, like climatic conditions, varying on the one hand from extremes of aridity (e.g., Upper Kundelungu, Upper Karroo, Oligocene) to extremes of glaciation (e.g., Lower Kundelungu, Lower Karroo)" (p. 43).

*Dwyka Glaciation.*

In the Congo Basin the Dwyka glaciation occurs in the lower part of the Lukuga beds, as described on an earlier page, and Dwyka tillites or striated floors are to be seen in at least five areas between 1°30′ and 10° S. Lat. and between 17° and 29° E. Long.

"The part of the Dwyka record still preserved shows, near the Equator, two ice advances and an interglacial deposit crumpled in places by the last ice advance. . . There are indications of a glacial lake at least 400 miles long, in which black muds were deposited, reaching a maximum thickness of 150 meters, and in places containing iceberg-transported erratics. The indication is of a topography of no great local relief in the Congo region, sloping, in general, from northwest to southeast" (p. 162). "To the north the movement of the Dwyka ice was, for a considerable distance, uphill, and the elevation of the land at the northern limit of Dwyka glaciation, on or just north of the Equator, was probably higher than at the centers of the accumulation" (p. 156).

"The Dwyka glaciation was essentially co-extensive with the late Proterozoic glaciation (Kundelungu-Pretoria-Griquatown); both originated from centers north of the Tropic of Capricorn; both had northern limits slightly north of the Equator and southern limits near the southern end of the present continent, with a maximum development north and south in Africa of probably over 2500 miles; and both were succeeded by a climate becoming progressively more arid and ending in a period of extreme aridity" (p. 162).

Throughout this memoir Veatch refers the Dwyka glacial beds to the Upper Carboniferous. He also thinks it well established that the late Paleozoic glaciation "began in Australia near the close of the Lower Carboniferous or the beginning of the Upper Carboniferous" (p. 154). Are either of these conclusions correct? The Australian reference has to do with the Seaham tillite in the upper part of the Kuttung series, which has the Rhacopteris flora, admitted by all paleobotanists to be of late Lower Carboniferous time, although the genus *Rhacopteris* itself is known very sparingly in the older Westphalian of the Upper Carboniferous. This same flora occurs associated with tillites in Argentina. In the writer's paper of 1928,[2] he wrongly referred the Seaham tillite to the Permian, but in 1932[3] he corrected this error, referring the tillite to the late Lower Carboniferous. This little known late Lower Carboniferous ice age of Australia and South America is

[2] Review of the Late Paleozoic formations and faunas: Bull. Geol. Soc. America, vol. 39, pp. 769-886, 1928.

[3] The Australian Late Paleozoic glaciations: this Journal (5), vol. 23, pp. 540-548, 1932.

unknown in Africa, and therefore Veatch's reference to Australia has no direct bearing on the Dwyka tillite of Africa; in fact, the writer believes that the two ice ages are separated by a hiatus having the length of the entire Upper Carboniferous (Pennsylvanian), a period of probably 40 million years' duration.

To the statement quoted above (from his page 154), Veatch added a footnote which reads as follows: "Charles Schuchert recognized in the discussion of the last paper [by Walkom, read before the International Geological Congress at Washington, 1933] that his earlier reference of the oldest part of this glaciation [Seaham tillite] in Australia to the Middle Permian was not well founded and that the beds are of Carboniferous age." As above shown, this is true so far as the Seaham tillite is concerned, but the present writer did not say at the Congress that the younger, Lochinvar tillite was also Carboniferous, as Veatch assumes. Far from it, since he held then, as he stated in his paper of 1932, and he still holds, that the Lochinvar tillite correlates with the African Dwyka and the Indian Talchir; the age of these three tillites, he thinks, "probably will turn out to be . . . early Middle Permian."[4]

Veatch also says that the main phases of the late Paleozoic glaciation "ended before the appearance of the *Eurydesma* fauna, which is variously regarded as marking the close of the Upper Carboniferous or the beginning of the Permian" (p. 154), and that the Dwyka tillite "is of pre-*Eurydesma* age" (p. 155). These statements apparently mean that Veatch regards *Eurydesma* as appearing in late Carboniferous time, and hence believes that the Dwyka series is of Upper Carboniferous age. The writer therefore asks, Has anyone found *Eurydesma* in strata belonging elsewhere than in the older half of the Permian? Not to his knowledge. Furthermore, wherever this marine cold-water bivalve appears, it is in strata that also yield the Gangamopteris-Glossopteris flora. In India, *Eurydesma* occurs abundantly in beds above the tillites of the Salt Range, and both tillites and *Eurydesma* beds go *unbroken* into strata yielding what appear to the writer to be late Middle Permian marine faunas. And in South Africa the Dwyka series is said to be in "complete conformity" with the Ecca series.

Haughton's studies of the Reptilia of the Lower Karroo beds of South Africa,[5] Veatch says, led the former to the conclusion "that these beds are of Upper Carboniferous age and that the glaciation must have been at the latest in the upper part of the

[4] Correlations of the more important marine Permian sequences. Bull. Geol. Soc. America, vol. 46, p. 25, 1935.

[5] Haughton, S. H.: The origin and age of the Karroo Reptilia. Compte Rendu. Internat. Geol. Cong., XVth Session, South Africa, 1929, vol. 2, pp. 252-262, 1930.

Carboniferous" (p. 154). This may be so, but as this far-reaching conclusion is not based on direct evidence, let us see what the indirect evidence consists of.

In the first place, attention should once more be directed to the statement of Du Toit that *Gangamopteris cyclopteroides* "has actually been found jammed in between the [Dwyka] boulder-bed and the glaciated floor near Strydenburg . . . while at Vereeniging well-preserved fronds were discovered by Leslie in a shaly layer in similar position right against the [older] Dolomite. These are important finds, since they show that the Glossopteris Flora was already flourishing in South Africa, while glacial conditions held sway."[6] This plant, it should be added, is one of the characteristic species of the older Glossopteris flora, an assemblage which no one has yet shown by direct evidence to be of Upper Carboniferous age.

Haughton, Broom (who has at least since 1913 been regarding the Dwyka series as of Permian age), and others have stated that no reptiles at all are known in the 2900 feet of the typical Dwyka series, or in the lower three-fourths of the Ecca series, with its thickness of 2000-6000 feet. It is near the top of the Ecca beds that the Dinocephalia appear sparingly in *Eccasaurus*, *Archeosuchus*, and possibly *Moschops*. These facts mean that a long interval of geologic time passed before the land-living reptiles appeared in South Africa.

Further, the specialized aquatic reptiles, *Mesosaurus* and *Noteosaurus*, found in the late Dwyka shales (White Band) of South Africa and in the Iraty shales of South America, are probably in both continents of a marine or at least an estuarine habitat. In support of this conclusion it should be added here that Ruedemann in 1929 showed the writer the following fossils from black shales in the state of São Paulo, Brazil: *Orbiculoidea*, *Lingula* cf. *L. melie*, and "*Conularia.*" The last-named turn out to be coprolites, probably of crossopterygian fishes which fed on lyssacine siliceous sponges (spicules are common) and palaeoniscid fishes (scales related to *Acrolepis* and *Elonichthys* are present).[7] This evidence shows that the Permian shales of the states of São Paulo and Paraná are largely of marine origin, or are at least interbedded with genuine marine strata. As the Iraty black shales with *Mesosaurus* are also marine (on the basis of their lithology), the reptiles of this marine formation probably therefore did not give origin to the reptilian land fauna of the Beaufort series.

Haughton also says, as bearing on his reference of the Dwyka series to the Upper Carboniferous, that "at the same time, it must be accepted that the cooler conditions [of Dwyka time] in which

[6] Du Toit, A.: Geology of South Africa, p. 214, 1926.

[7] See Ruedemann, R.: Fossils from the Permian tillite of São Paulo, Brazil. Bull. Geol. Soc. America, vol. 40, pp. 417-426, 1929.

it [the reptilian fauna] found itself must have speeded up the rate of evolution and the formation of reptiles to whom such a cold environment was not deleterious" (p. 261). In this connection, it is important to ask, first, where did these ancestral reptiles live? No one knows, but Haughton looks for this stock in Antarctica or southern South America. However, none is known there, nor does he tell us by what possible route they got into Africa. Furthermore, that a cool climate "must" be a stimulant in the evolution of cold-blooded reptiles the writer very much doubts, and the conclusion is new to him; at least, the idea is not helpful in the present discussion. If Haughton had cited aridity as a stimulant in the evolution of some late Carboniferous reptiles (but where?), there would be no objection to the hypothesis. The writer, however, looks for the evolutionary center of the late Carboniferous = early Permian reptiles in northeastern Africa-Arabia-Persia, whence they could more or less easily have spread, in late Ecca time, on the one side into South Africa, and in the other direction into the regions which are known to have related reptiles, namely India, Russia west of the Urals, and Scotland. In other words, Haughton's argument in support of his contention that the Dwyka is of Upper Carboniferous age is seen not to be convincing.

How, then, can my friend Veatch say that the Dwyka tillite is "Upper Carboniferous" in age, as he does throughout his memoir.[8]

In the writer's paper of 1935, he said: "The Punjabian clastics [of the Himalayas] also go unbroken downward into the basal Permian Talchir tillites. . . The age of the tillite should, therefore, be earliest Middle Permian . . . In Australia, on the other hand, the equivalent tillites lie beneath the Marine Series, which, according to [F. R. Cowper] Reed's work, has the same faunas as the Punjabian, but here again the sequence is broken, for beneath the tillite and its equivalent marine boulder bed lies the Lower Carboniferous (Kuttung [capped conformably by the Seaham tillite]). Consequently, one can not as yet prove in detail the age of the Permian ice time, other than to say that it surely is younger than any part of the Uralian, and probably will turn out to be of early Middle Permian age; *this is the most important unadjusted problem in the stratigraphy of the Permian*" (p. 25).

CHARLES SCHUCHERT.

[8] This paper was sent to Doctor Veatch for comment. Under date of October 7 he writes: "I now see that I misunderstood and misinterpreted your statement before the International Geological Congress at Washington in 1933, and I welcome your review straightening this out. I thought I was following you."

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