

THE KARROO BEDS OF THE WARMBAD DISTRICT,
SOUTH-WEST AFRICA.

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By S. H. Haughton, D.Sc., and H. F. Frommurze, B.Sc.

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and Industries.)

[Plates VI and VII.]

Although the presence of a large extent of Karroo Beds in the Warmbad District of South-West Africa has been known since the work of Dr. Range, and a very generalised idea of their distribution given on the published maps of Range, Wagner and du Toit, no detailed examination of their nature and distribution seems to have been made until the geological survey of the area was begun in 1926.

During the course of that work the beds (including the Karroo dolerite sheets) were found to have an area considerably greater than that previously supposed and to possess features of somewhat unusual interest in their geographical relations to the older rocks; and it is felt, therefore, that a brief account of them and of their bearing on the history of Carboniferous glaciation would be of some value to other workers.

The rocks preserved in the area are divisible into Dwyka Tillite, Upper Dwyka Shales, and Ecce Beds—the whole being cut by sheets of Karroo Dolerite. As will be seen in the sequel, the Dwyka Tillite is a two-phase one, some of the sediments comprised within it being the work of the Namaland ice, and the remainder deposited from the Griqualand West ice.

The maximum thickness of the sequence is not less than 1,800 feet, made up of Tillite 200 feet, Upper Dwyka Shales 600 feet, and Ecce Beds 1,000 feet.

DWYKA TILLITE.

The beds assigned to the Dwyka Tillite in the Warmbad District are of two distinct facies. The one type, the main mass of which is developed in and around the Bondelswart Reserve, consists mainly of blue-grey boulder mudstones with intercalated shales; the other, which is chiefly confined to the neighbourhood of the Orange River between Viol's Drift and Nabas and the mining area of Aiais, is similar to the brick-red weathering type briefly described by Rogers from the Richtersveld.

(a) *Normal Type*.—The “boulder-mudstone” variety of Dwyka Tillite covers a considerable area, forming a large part of the country north of a line running from Uheib No. 84 through Tsacharaibes, Luginsland, Hochland and Haib Poort to near Viol’s Drift on the Orange River, and west of Nieuwefontein Ost No. 54 to Gaibes No. 1. The greater part of the Glacial Beds in this area occur as boulder mudstones with soft blue or grey argillaceous matrix, except where hardened by igneous intrusions. The inclusions are mostly small, but occasional patches are found where boulders four feet and, more rarely, six feet in length are found. The most common inclusions are of Kuibis quartzites, amygdaloidal lavas, cherts, jasper, porphyry and granite. Shales occur intercalated with the boulder beds and, in places, are also found below them. Owing to intrusions of Karroo dolerite sheets and sills, the rocks are in places considerably altered, becoming harder and lighter in colour. This is particularly noticeable in the calcareous tillite at Dreikameelbaum, where the normal bluish calcareous matrix has become white and recrystallised. The shales at the same place are baked to a white china-like consistency.

This normal type can be studied in numerous localities, short descriptions of a few being given as examples.

At Nieuwefontein Ost No. 54 the tillite is very thin and contains irregular patches of limestone, which are composed in part of gritty masses of gravel. In the northern part of this farm the olive-green and chocolate shales below the tillite showing in the stream-beds probably belong to the upper part of the Kuibis Beds.

On the south part of Nieuwefontein Ost and on Gross Aub the tillite is not more than 20 to 30 feet thick. It contains very few large boulders, most of its inclusions being small and angular. Associated with it are thin shaly mudstones containing no pebbles. Small patches of gneissose granite protrude through the tillite.

A short distance to the south of Bult trigonometrical beacon on Kalkfontein South are good exposures of the greenish shales below the tillite; amongst these shales are thin layers of calcareous sandstone.

In the Bondels Reserve, about three miles to the east of Gabes, the base of the tillite is well exposed. It forms a low escarpment about 10 to 12 feet high resting on granite. A similar feature is seen on Luginsland and Schonau, where a higher escarpment marks the base of the tillite. At the latter places the base of the tillite is very bouldery, many large boulders from the Griquatown and Pniel Series being obvious.

West of Kalkfontein, along the road to Guigaib in the Bondels Reserve, the higher ground is generally formed of tillite or shales, the trigonometrical beacons Jacobsplatte and Hugel both being situated on tillite eminences. The whole area here appears to be underlain by a dolerite sheet which shows in the stream-channels; around the hill on which the Hugel beacon stands shales of Karroo type underlie the dolerite.

Progressing to the west, a rise in the surface of the country corresponds to a gradual change from the highly conglomeratic tillite containing many boulders to a mudstone with small and rare inclusions.

In the neighbourhood of Guigaib the tillite is replaced by a well-bedded fine-grained mudstone in which inclusions are small and few in number, the horizontal banding in the rock going over or under these inclusions. This rock may be compared closely with the Varve clays of the Pleistocene glaciation, and suggests deposition in still water. In places here these horizontally bedded mudstones, which contain small grains of quartz, felspar, etc., scattered through them, are contorted and limestones are also present. All the rocks here are highly baked by the intruded dolerite.

At Driehuk, a few hundred yards to the north of the Native Superintendent's house along the river, are some cliffs about 100 feet high which give excellent sections of the Dwyka resting on the older rocks. Immediately above the gneiss, which is coarse-grained, porphyritic and contains garnets, are about five or six feet of a compact greenish shale; this is followed by four feet of a conglomerate composed almost entirely of angular pebbles. Above the latter come 50 feet of bluish mudstone containing a few small pebble inclusions. The rest of the section is made up of grey and green splintery shales. The matrix of the tillite is sometimes calcareous or siliceous here. At Haib the tillite contains many large boulders, amongst which ancient amygdaloidal rocks are prominent. The boulders here are often four feet long and the rock gives rise to a boulder-strewn veld. The matrix of the boulders is a joint-clay, very like many in the Cape Beaufort Beds. Large and small phosphatic nodules containing fish-scales and bones are common.

In the south-western corner of Hierachabis, just north of the railway line, occurs a fairly large outlier of Dwyka tillite and shales covering an area $3\frac{1}{2}$ to 4 square miles in extent. Outcrops are scarce and the underground presence of the Dwyka formation is indicated by numbers of large foreign boulders resting on the surface. The tillite has the characteristic grey-blue matrix and contains many large inclusions, boulders 4 feet in length being common. Prominent among these are boulders of Pniel amygdaloids and grits and Kuibis quartzites. A peculiar feature here is the presence of patches of highly calcareous and gravelly tillite. These are more resistant to weathering than the argillaceous varieties, and hence are more prominent.

The total thickness of the tillite here does not appear to be very great, as in a well to the west of the dolerite boundary only 40 feet of tillite was penetrated, shales of the Kuibis beds lying below. In further support, may be quoted the number of domes of Kuibis quartzite which protrude through the tillite mantle. One of these latter, situated north-west of the Grasvlei trigonometrical beacon, is striated, the direction of the scratches being S.30°E. The high easterly dip of the Nama under the tillite seems to indicate that this outlier of

the Dwyka has been preserved by being deposited in a large fold in the Nama beds.

(b) *Red-weathering Type*.—This type is practically confined to the area west of the Bondelswarts Reserve and is continued southwards across the Orange River, being well developed there near Nabas and to a less extent south of Viol's Drift.

The beds consist of thin-bedded sandy mudstones, massive contorted mudstones, flagstones, buff, brown and pink quartzitic sandstones, and thin bedded siliceous shales with lenticular beds and layers of boulder beds and masses of brown-weathering limestone, sometimes containing grit layers. The boulder beds occur at various levels, whilst throughout the beds small striated pebbles are scattered sporadically. The boulder beds contain beautifully striated boulders and pebbles, large and small, usually of granite or quartzite, closely set in a hard, gritty matrix. Boulders up to four feet in length were observed. The thin-bedded siliceous flagstones are frequently ripple-marked and rill-marked; and invertebrate tracks are very numerous at some localities. The brick-red weathering of the rocks of this variety makes them a conspicuous feature in the areas in which they occur.

The most easterly occurrence of this type—apart from one small outlier far to the north-east on Ukamas—is at Haib Pcort, where a thin band rests on striated surfaces of fine-grained gneiss. The tillite here consists of buff-coloured sandstones with numerous inclusions. It is overlain by a series of finely-laminated multi-coloured shales which contain no inclusions.

Eastward to Viol's Drift it is apparent that the Dwyka was deposited on a very uneven floor; red and yellow ripple-marked sandstones and mudstones at the base have their bedding-planes conformable with the inequalities of the pre-Dwyka surface. It is noteworthy that in some places the very bottom layer of reddish sandy mudstone adheres strongly to the underlying rock and has its upper surface grooved and polished by ice-action.

Around Klipneus and Nabas on the Orange River the type is well exposed; and there are a number of very interesting outliers occurring in synclinal basins in the Aiais mining area. A noticeable peculiarity of the sandstones is the fact that they weather yellowish-brown with curved layers richer in iron oxides than the rest of the rock, and consequently darker in colour.

The thickness of this type of Dwyka is very variable. Occasionally, as north of Kanibeam, the Tillite is altogether absent, and the upper shales overlap on to the gneisses and schists. A few miles away the sequence is about 200 feet thick.

Relation of the Two Types.—What may for convenience be called the "red" and "blue" types of Dwyka Tillite in general occupy areas distinct from one another; but occasionally outcrops are found where the relations between the two can be studied.

North-east of the Sjamboks River mouth, in the valley of the Chorab (south of Aussenkehr), the base of the Tillite consists of red and yellow-weathering flagstones with invertebrate tracks and crumpled mudstones. These are overlain by blue-weathering boulder-conglomerate with large masses of "Gravel Dwyka." Striated surfaces of Nieuwerust quartzites occur just south of this, the striae running north-south.

On the farm Gaibes No. 1 and near Sandrucken beacon the usual beds of the Dwyka are built up of a considerable thickness of red and yellow flagstones, ripple-marked sandstones and contorted mudstones with occasional large and small striated boulders. Covering them is Tillite with a bluish-green matrix crowded with small pebbles, which passes upward into green and black shales. The same sequence is seen west of Sandrucken beacon on the road from Gaibes to Aiais.

The evidence from the whole area seems strong in favour of the view that we are dealing here with deposits belonging to two distinct ice-sheets, called by du Toit the Namaland ice and the Griqualand West ice. The deposits from the former are characteristically red-weathering and the glaciated surfaces show that movement was in a north-south direction. The most easterly occurrence of this type is near Ukamas, where pink shales and pebble-beds lie in a small depression on a surface of Kuibis quartzites which is in part plucked and in part striated. The deposits from the Griqualand West ice are bluish-green in colour, contain boulders of far more varying type, and the glaciated surfaces below them have striae running approximately west-south-west (Nieuwefontein, Uheib, Kanus).

Further, it is apparent that the Namaland ice was the earlier in this region. Wherever the two types are in contact, the boulder-mudstone overlies the "red" type; and the latter never passes upward into the Upper Shales without some obvious break or the intervention of greenish beds carrying erratics. The passage from the boulder-mudstone into the shales is always a gradual and almost imperceptible one, the inclusions become smaller and fewer and the matrix finer-grained and thoroughly argillaceous.

Conditions of Deposition.—At Zwartbas, west of Viol's Drift, a most interesting exposure occurs. The Orange River here runs due south for a short distance, and its right bank is a steep cliff formed of Malmesbury mudstones and limestone conglomerate. These beds are most magnificently glaciated—polished, rounded, channelled and striated—many of the polished faces being nearly vertical. Here and there, against these faces and in small hollows, Dwyka rests. The basal Dwyka consists mostly of yellow impure limestone or shales with very few erratics; but occasionally there is a thin veneer of Tillite closely attached to the Malmesbury, and in one exposure this veneer (not more than $\frac{1}{4}$ inch thick) is itself scratched and striated. The Tillite here is thin, some of it dips to the east at about 30° ; but a few yards to the north of the section Upper Dwyka Shales suddenly come in and lie nearly horizontally.

Similar glaciation of a thin veneer of Tillite is seen north of Viol's Drift; and it is obvious that we are dealing here with a succession of advances and retreats of the Namaland ice-sheet, which must have passed over a very uneven surface.

The general nature of the "red" Dwyka precludes it from being considered as a true moraine. The preponderance of flagstones and mudstones, the comparative lack and lenticular nature of the boulderbeds, the presence of ripple-marks and invertebrate tracks, and the obvious bedding all point to the deposition of material in comparatively shallow water, the material itself being in the nature of outwash from the glaciers, which, further to the north, deposited their thick moraines in the area south of Gibeon. This outwash must have been largely consequent on the final retreat of the Namaland ice which had previously extended as far south at least as the Orange River; and this retreat must have largely preceded the westward extension of the Griqualand West ice, as formulated by du Toit.

The irregularity of the surface over which the Namaland ice moved and on which the outwash material was deposited is very evident, in spite of the post-Karoo warping which has tended to alter its features. One of the most interesting conclusions that has arisen from a survey of the area is that some of the present-day topography of the Orange River valley between Viol's Drift and Kwabs Drift is formed of pre-Karoo features, particularly the prominent cliff of Malmesbury limestone which forms the eastern and northern limits of the Neint Nababeep plateau in Namaqualand.

Rogers has found post-Dwyka faulting south of Viol's Drift; but this faulting is only local and does not extend north of the river—the relations of the Dwyka to the older rocks between Viol's Drift and Haib Poort being those of an ordinary unconformity which has suffered subsequent warping. Again the verticality of some of the glaciated faces at Zwartbas cannot be explained by subsequent warping, and these can only be considered as sides of depressions in the surface of the Malmesbury down which the Namaland ice moved.

Minor irregularities of the surface are fairly numerous. It would seem, too, as if the area of deposition was bounded on the west by the range of hills which run north from the Orange River at Chamgabmund and culminate at Dreikopf; but to the north of that peak the depression in the surface extended westwards at least to the Fish River, as remnants of "red" Dwyka rest on a slightly uneven surface of Nama or of granite on Karius and Geiaus.

To the east, pre-Dwyka topography is preserved on Nieuwfontein Ost and the neighbouring farms down to the Ham River. In this area Tillite of the boulder-conglomerate type rests against cliffs of Kuibis quartzite, with a dolerite sheet cutting both formations. There can be no question of faulting here, and the Nama cliffs must be a pre-Dwyka feature. Elsewhere, as on Heirachabis, peaks and domes of the older rocks project through the Dwyka covering.

THE UPPER DWYKA SHALES.

As stated above, the "blue" type of Tillite passes up gradually into the Upper Dwyka Shales. These also overlie the "red" type of the west, but where there is no obvious unconformity (as there is at Zwartbas), the two are always separated by a band of blue rock containing boulders and pebbles and, frequently, limestone concretions.

In the area east of Haib the upper shales are not a consistent feature, but, owing to subsequent erosion, are only found in patches on the tillite. They are for the most part soft green and blue, sometimes yellow, thinly bedded mudstones. In places limestone bands are developed.

West of Haib, however, the upper shales cover the tillite altogether for many miles, and reach their maximum development at Eisenberg in the north-western corner of the Bondels Reserve. Here the rocks are yellow, green, grey, pink and blue shales, which break up into irregular fragments; they have interbedded with them lenticles and thin bands of dark-weathering impure limestone—sometimes pyritic—and concretionary nodules which show "snuff-box" weathering. These layers are never more than 2 feet in thickness. Similar but thinner bands and lenticles occur of dark-coloured phosphatic rock, while scattered throughout the shales are occasional small pebbles and nodules. The total thickness of shales at Eisenberg is about 500 feet.

Near Westblik beacon, to the north of Haib, there is a remarkable development of light-blue and grey limestone layers in the shales. These limestones are highly pyritic, and the cubes of pyrites weather into rusty brown prominences on the surface. In this neighbourhood the shales immediately above the tillite are highly folded and much contorted.

The "White Band" forms the top of the Dwyka Series. It is composed of very fine-grained thin-bedded black shales which weather to a white colour, especially near the contact with a dolerite sheet. The weathered portions of the outcrop contain thin beds of gypsum. The White Band is particularly well developed in the western part of the district, near Aussenkehr and in and near the valley of the Chamgab. The width of its outcrop in this valley south of Aiais is considerably increased by gentle folding. The identity of this band with the "White Band" of the Union is based not only on its position with respect to the Tillite, but also upon the discovery within it at Kanibeam of moulds of the bones of *Mesosaurus* sp.

THE ECCA SERIES.

The Eccla Beds form an area of high ground some 300 square miles in extent between the Chamgab River valley and the Kakab Vlei depression. The area is a plateau-like one with "table-mountains" resting on it; of these, Neidi Berg, Amib Berg (2,690 feet—partly covered with dolerite), and Tafelkop (2,818 feet) are the most prominent.

The beds consist of thin yellowish shales which weather brown, green shales, thin limestones—ferruginous in places—sandy shales and, in the upper part, light-coloured sandstones. Yellow-weathering limestones showing cone-in-cone structure are fairly common, and there are in some of the shales large lenticular masses of brown-weathering limestone. Near the base of the beds, south of Gaibes, there occurs a band of massive white chert accompanied by thin limestones.

The Ecça Beds are folded into a series of shallow synclines and anticlines. The highest horizon is exposed in the centre of the basin in the Amib Mountains.

Fossil wood, somewhat phosphatic, is fairly common in the beds; but apart from some fragments of unidentifiable bony plates no other fossils were seen.

THE KARROO DOLERITE.

It is not intended in this paper to deal at length with the Karroo dolerites, of which there are at least three distinct sheets in the area. A striking feature is the fact that, although these sheets are very extensive, dykes are scarcely represented. Again, although small sheet-like intrusions do occur in some of the pre-Karroo rocks, it is noticeable that the sheets are mainly confined to the Karroo sediments—in the Orange River area entirely so. The dolerite has produced a strong baking effect upon the sediments which it cuts. Wherever it occurs it forms a marked feature of the landscape.

POST-KARROO DEFORMATION.

Throughout the basin occupied by the Karroo Beds there is evidence of post-Karroo warping. In general the folding produced is gentle. Near the western edge of the area, however, there is a sharp fold with its axis running about N.N.E. and the dip of the beds up to 70° to the E.S.E. This fold is well displayed in the Upper Dwyka Shales and dolerite east of Sandrucken beacon; when traced to the south the fold becomes a fracture with downthrow on the eastern side.

Another fault must be present to the west of Norachas hill. Here there is a difference of level of about 600 feet between the White Band in the Chamgab valley and the same band on Norachas hill. This difference cannot be accounted for by folding, as the beds lie almost horizontally at each place, except that—at the presumed fault—there is a sudden warping and the shales dip at about 60° to the E.S.E., as if they had been dragged down on the downthrow side of the fault. This fault must run through the Kakab Vlei depression and down towards Haib Poort, near which place it brings the upper and lower dolerite sheets almost into juxtaposition.

FOSSILS.

The Dwyka Tillite of the south-western part of the area yielded numerous slabs showing well-preserved tracks of invertebrates. Most of these are of the type usually called "crustacean," and the specimens collected seem to show the presence of several distinct forms. Other markings are more of the nature of the trails thrown out by a boring mollusc or, possibly, by a worm. There was obviously a fairly abundant shallow-water fauna in certain areas, possibly living in pools fed by the mud-carrying streams from the melting ice. That these pools suffered partial desiccation is shown by the presence of sun-cracks, which do not, however, occur on the slabs carrying the tracks.

Fragments of fossil wood were also found in the Tillite.

From the Upper Dwyka Shales a more definite fauna was obtained. Nodules from the base of the beds near Haib yielded fish-scales and a fragment of a large Amphibian (?) bone. From a slightly higher horizon near Haib came a *Mytilus*-like lamellibranch which may be referred to as *Myalina* (?) sp., and the mould of part of a coiled shell which is presumed to be a gasteropod. The same beds also yielded a number of peculiar U-shaped burrows filled with calcite and enclosed in nodular laminated shale hardened with ferruginous cement. Dr. F. A. Bather has identified them as worm-burrows and has compared their mode of occurrence to the U-shaped burrows from the Upper Charmouthian of France named *Tisooa siphonalis*.

Nodules from the base of the shales near Viol's Drift contained fragmentary fish, one of which can fairly definitely be assigned to the genus *Acrolepis*. The "White Band" at Kanibeam contained a few moulds of bones of *Mesosaurus* sp.

Fossil wood was found both in the Upper Dwyka Shales and in the Ecce Beds, being particularly abundant near the base of the latter.

APPENDIX.

Attention may be drawn here to the recent discovery by us of Echinoid remains in a calcareous nodule from the Dwyka Shales near the main road west of Brukaros Siding, north of Tses. The remains consist of a number of fragmentary ambulacral plates and of portions of spines which have most of the characters of the corresponding portions of the genus *Archaeocidaris*. Each plate carries a prominent median perforate tubercle with a wide scrobicular area bounded by a prominent ring. It is possible that the scrobicular area was covered with a series of radial grooves; but the evidence for this is not conclusive. The plate seems to have carried no secondary tubercles. The spines are large, cylindrical at the base, with a series of grooves running from the acetabulum to the collar. Some of the spines were apparently furnished with spinules on the shaft.

This is the first record of Echinoid remains from the Dwyka Series, and is of interest when considered in connection with the occurrence

of *Orthoceras* in a calcareous nodule in the Tillite at Tses, recorded by du Toit. This *Orthoceras* is fragmentary. Its length as preserved is 53 mm., and the diameter of its circular cross-section in the middle of the specimen is 16 mm. The septa are about 7·5 mm. apart. The shell is straight, and but slightly tapering, smooth except for faint transverse growth-lines. The siphuncle is slightly excentric.

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