

EXPLANATION OF PLATE XV.

Steganoblastus ottawaensis.

- FIG. 1. Specimen A, from the posterior interradius, showing periproctals and, above them, the supposed hydropore.
 ,, 2. Specimen B, from the posterior interradius, showing the same features.
 ,, 3. Specimen A, the lip of the anterior subvective groove, showing pores, adradial suture, and spine-pits. For exigencies of lighting, the perradius is sloped downwards from right to left. × 5 diam.
 ,, 4. Specimen A, from the right anterior interradius.
 ,, 5. Specimen B, adoral view; compare Text-fig. 5.
 ,, 6. Specimen A, adapical view.
 ,, 7. Specimen A, adoral view; compare Text-fig. 6.

All the figures are from photographs by Mr. H. G. Herring, and all, except Fig. 3, are enlarged 3 diameters.

The Text-figures are based on pencil drawings by Mr. G. T. Gwilliam.

II.—THE ZONES OF THE BEAUFORT BEDS OF THE KARROO SYSTEM IN SOUTH AFRICA.

By D. M. S. WATSON, M.Sc., Lecturer in Vertebrate Palæontology in University College, London.

PROFESSOR H. G. Seeley, in his well-known paper on *Pariasaurus Baini*, incidentally mentioned that the Beaufort Beds, in which it was found, could be divided up into zones on the evidence of the reptiles they contained. Dr. R. Broom, following out this suggestion, went further and divided them into the

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| <i>Cynognathus</i> <i>Procolophon</i> <i>Lystrosaurus</i> <i>Cisticephalus</i> <i>Endothiodon</i> <i>Pariasaurus</i> | } | Zones. |
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This division is perfectly correct and cannot at present be improved upon, but beyond saying to which zone all the species which he recognized as distinct belong, Broom has never offered any evidence in support of it or indeed explained the real meaning of the division.

During my visit to South Africa I had the good fortune to collect from all these zones, and propose in this short paper to explain the evidence I collected and then to show that from the evidence of specimens in museums it is possible to construct a map which is self-consistent.

The three lowest zones are best seen round Beaufort West. Beaufort West stands on the *Endothiodon* zone, and to the south there is a great expanse of slightly rolling country, the Gouph, which is obviously composed of rocks lying below those on which the town is built. To the north the magnificent escarpment of the Nieuvelid rises about 3,000 feet above the plain.

The beds which form the Gouph have been very extensively collected from by T. Bain, H. G. Seeley, The Survey, R. Broom, J. H. Whaits, and the author. They yield several species of Pariasaurus, none of which have an armour more extensive than

that of *Pariasaurus Baini* as described by Seeley, that is, they have only a few small scutes round the neural spines of the dorsal region. Less common are the remains of Deinocephalia, both Tapinocephaloids and Titanosuchia and many diverse types of Therocephalia. Small Dicynodonts occur in considerable numbers, but no large forms of Anomodont have ever been found, and the beds have been so thoroughly searched that their absence or excessive rarity is assured.

The *Endothiodon* beds, which are seen in the field to follow those of the *Pariasaurus* zone, have been searched by T. Bain, very largely by J. H. Whaits, and to a much less extent by the author. They have never yielded any Pariasaurian remains (except a very small femur) and no Deinocephalians. There are many Therocephalia, particularly Gorgonopsids, including *Gorgonops torvus*. There are numerous large Endothiodons, and all the Dicynodonts are very small.

At the top of the Nieuveld escarpment, for example at Kuils Poort Nek, about 12 miles north of Beaufort West, there is a fauna, collected at various places along the escarpment by T. Bain, H. G. Seeley, R. Broom, The Survey, J. H. Whaits, S. H. Haughton, and the author, which has as its commonest and most striking constituent large Dicynodonts, i.e. types with a skull length of 25 cm. or more. There are also Therocephalia and Gorgonopsids, quite different from those found below, and the much armoured Pariasaurians of the genus *Propappus* occur in considerable abundance. Judging from this district, which has been so extensively worked as to afford most satisfactory evidence, the zones are characterized by the following features:—

The *Pariasaurus* zone, by the occurrence of large, slightly armoured Pariasauria and Deinocephalia and the absence of any large Anomodonts.

The Endothiodont zone is characterized by the occurrence of *Endothiodon* and other large Endothiodonts and peculiar Gorgonopsids, and by the total absence of large Dicynodonts.

The *Cisticephalus* zone is characterized by the presence of many large Dicynodonts and *Propappus*, and other much ornamented Pariasaurians and the absence of any large Endothiodonts.

The three upper zones can only be studied in the east of Cape Province. Round the towns Aliwal North and Burgersdorp the *Cynognathus* zone is very well exposed, and has been collected from by A. Brown, R. D. Kannemeyer, R. Broom, and the author. It yields a fauna the most abundant constituents of which are the large Dicynodonts of the genus *Kannemeyeria*, Cynodonts, particularly those of the family Cynognathidæ, and the Thecodont *Erythrosuchus*.

Passing north-westward of the rich locality of Winnaarsbaken at the farm Klip Kuil, a bed of extremely hard sandstone with clay galls and fragments of bone is clearly seen to dip under the *Cynognathus* beds. In this bed I found fragmentary limb-bones apparently of *Lystrosaurus*, and two complete maxillæ and a dentary of *Procolophon trigoniceps*. In the river which intersects this bed and about 200 yards below in a bed of sandstone about 100 feet below that which contains *Procolophon*, I obtained *Lystrosaurus* remains,

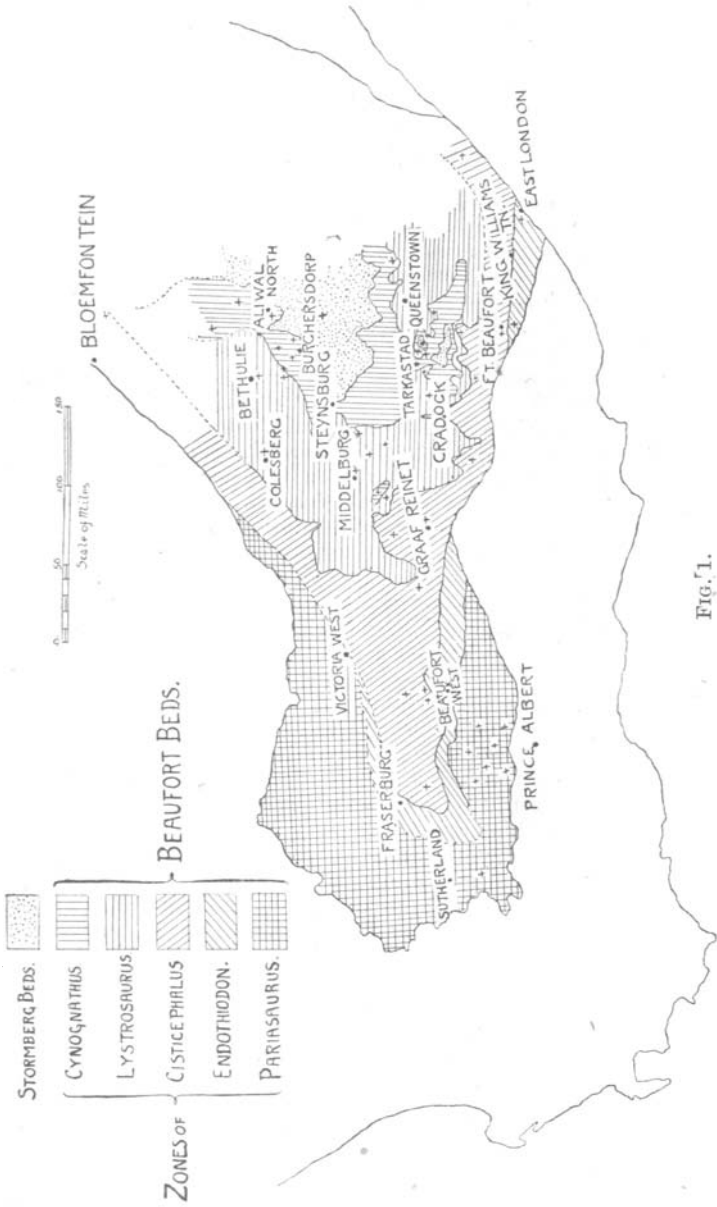


FIG. 1.

Geological Sketch-map of South Africa to illustrate the distribution of the zones of the Beaufort Beds. The bottom of the Beaufort Beds is copied from Rogers & Du Toit's map on the geology of Cape Colony. Crosses are selected fossil localities, yielding fossils of the zone in which they lie. The *Procolophon* zone is represented by the line between the *Lystrosaurus* and *Cynognathus* zones. Judging from this map it is highly probable that there should be an exposure of the *Endothiodon* zone south of (Fearston, but I know of no field evidence of its occurrence).

one skull being apparently *L. curvatus* (Owen). Further to the west, at Venterstad and Bethulie Bridge, *Lystrosaurus* again occurs, specimens being in the British and Albany Museums.

About 80 miles south of Burghersdorp, in the district round Tarkastad, I again obtained clear evidence of the order of superposition of these three zones. In the Field Cornetcy Upper Zwaart Kei of District Queenstown there is a hill, Tafelberg, the watercourses on the sides of which give excellent sections. At two localities, Haslop Hill to the north-east and Donnybrook to the south-west of this hill, I obtained *Procolophon* at nearly the lowest level explored. This reptile occurs in a thin zone in the great mass of deep-red mudstone which forms all the lower part of the hill.

On the farm Tentergate, which is on the west side of Tafelberg at a horizon about 500 feet above the *Procolophon* zone of Haslop Hill, I found in a thin sandstone a broken dentary of *Tribolodon frerensis*, the type-specimen of which was found by Professor Seeley in the *Cynognathus* zone of Lady Frere. The upper part of Tafelberg is composed of grey shales and yellow-grey sandstones, which are lithologically similar to the Molteno Beds. In the Albany Museum there is a dorsal vertebra of a Dinosaur collected by Mr. D. White at Tafelberg; as no Dinosaurs have ever been found in the Beaufort Beds, this affords very strong evidence that these grey beds are really of Molteno age. About 20 miles west of Tafelberg, in the lowest beds exposed in the farm Newtondale, I obtained *Lystrosaurus declivis* (?) in a deep-red sandstone and fragmentary *Lystrosaurus* remains in a yellow sandstone. These beds are the lowest of those occurring on this farm, and are clearly seen in the field to lie below the *Procolophon* zone of Haslop Hill. The only common animal of the *Procolophon* zone is *Procolophon* itself.

The *Lystrosaurus* zone is characterized by that animal, which occurs almost to the exclusion of other forms; there are in the British Museum some peculiar large *Dicynodon* skulls from Bethulie which seem to have come from this zone.

The *Cynognathus* zone is sharply marked by *Kannemeyeria*, *Cynognathids*, and *Erythrosuchus*.

Accepting the possibility of identifying these zones by the facies of the fauna they contain, a presumption which is justified by all experience and by the great length in time of the zones (the six cover the entire interval from low in the Permian to near the top of the Trias), it is easy by determining from specimens in museums the horizon of a sufficient number of localities to construct a geological map. This is done in Fig. 1 (p. 205), where the crosses represent some known fossil localities almost all represented in the British Museum. I do not intend to give a list of these localities and the fossils from them, because it is difficult to do so usefully without a systematic revision of the South African fossil reptiles. The more important and critical localities are discussed below.

The *Procolophon* zone is so thin that it cannot be separately represented, but is indicated by the line of junction of the *Lystrosaurus* and *Cynognathus* zones. *Procolophon* has been found at Whittlesea and Donnybrook, Queenstown District; Haslop Hill,

District Tarka; Fernrocks, near Tafelberg Station, District Middelburg; Klip Kuil, District Albert; and at a locality on the Orange River a few miles west of Aliwal North. It also occurs in the Orange Free State. These localities fix the line with some accuracy and give the bottom of the *Cynognathus* zone, the upper limit of which is the bottom of the Molteno Beds, whose outcrop has been partly mapped by the Survey and is obvious from their marked lithological characters. The field evidence seems to show that the upper part of the Great Winterberg is composed of Molteno Beds formerly continuous with those of Tafelberg. The area of *Cynognathus* beds north-west of Graaf Reinet depends on the type-specimen of *Cynochampsia laniaria*, Owen, from Rhenosterberg. This specimen is quite certainly a Cynognathid, almost certainly a Diademodon. The most northerly *Cynognathus* zone locality which I know is Smithfield, from which the British Museum has *Erythrosuchus*.

The distribution of the *Lystrosaurus* zone is well fixed by the occurrences at Klip Kuil, Colesberg, round Middelburg, and Newtondale in Tarka. North of Fort Beaufort its distribution on the map depends on a thick mass of light-yellow sandstone which I believe to belong to this zone. Large Dicynodons indicating the *Cisticephalus* zone are found at many localities round Fort Beaufort. The occurrence of the type-specimen of *Pariasaurus* at Blinkwater suggests the occurrence of the zone of that name, but specimens in the British Museum which I have strong reasons for believing to belong to that type-specimen are of a type which would now be called *Propappus*, a typical *Cisticephalus* zone form.

The occurrence of the type-specimen of *Gorgonops torvus* at "Mildenhalls", which is probably the farm now owned by the family of that name a few miles south of Fort Beaufort, shows definitely the occurrence of the *Endothiodon* zone, for another and absolutely identical individual has been found in the zone at Beaufort West. The small Endothiodonts found at East London suggest the same horizon, though they might be of *Cisticephalus* age.

The *Cisticephalus* locality north of Bedford is on the Kagaberg, where *Dicynodon tigriceps* occurs, that near Aberdeen depends on the type-specimen of *Platypodosaurus robustus*, Owen, from Camdeboo. Large Dicynodons probably of this horizon in the Bloemfontein Museum come from the Modder River about 20 miles east of that town. Similar but very fragmentary remains have been obtained at Senekal and Harrismith.

The typical large lightly armoured Pariasaur of the zone of that name have never been found except in the Gouph. The Deinocephalian *Mosops* comes from Dams Laagte, south of Sutherland. As the large bones of these reptiles when weathered out are only very slowly destroyed and are very conspicuous objects, the fact that they have never been found elsewhere gives good reason for believing that this zone either does not occur out of this district or, much less probably, is not fossiliferous.

The map constructed in this way from many more localities than those actually marked is self-consistent, and I think does make an approximation to the real general distribution of these zones in

those regions, a wide strip between Aliwal North and Fort Beaufort, and the district round Beaufort West, of which I have a personal knowledge. It is, I hope, fairly satisfactory, but the country between Graaf Reinet, Beaufort West, Victoria West, and Colesberg has as yet yielded so very few fossils as to be in the last degree speculative. The Free State fossils are so few and so badly localized that that province is practically a *terra incognita*. The most interesting feature is the occurrence on Harrismith commonage of *Lystrosaurus*, a large *Dicynodon*, and typical Dinosaurs of the Red Beds of the Stormberg Series, a fact which seems to indicate plainly a thinning out of the *Cynognathus* zone and Molteno Beds, and that overlap of the Stormberg Beds into older rocks which we know to have occurred in that direction: There is evidence of the occurrence of *Cisticephalus* and *Lystrosaurus* beds in Natal.

The map brings out clearly the fact that the Karroo rocks lie in a basin formed by two shallow synclines whose axes, running approximately east and west and north and south, meet in the Transkei, and that they dip at an extremely low angle to the east and the south respectively.

I have in connexion with this paper to thank the Trustees of the Percy Sladen Fund, who assisted me to visit South Africa, many farmers in Cape Colony too numerous to mention separately, and particularly my friends Dr. R. Broom and the Rev. J. H. Whaits, whose knowledge is invaluable.

III.—PERIODS OF DREIKANTER FORMATION IN SOUTH NOTTS.

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(PLATE XVI.)

IN the summer of 1911 I discovered numerous wind-worn stones in a gravel-pit near to Ramsdale, and situated at the side of the Old North Road 6 miles out of Nottingham. Samples of these were exhibited at the Geological Society's conversazione in 1912. During the next few months a trench for the water-main from the Derwent valley to Nottingham was opened along this road, and passed for a distance of over a mile through similar gravels, which in one place were at least 10 feet thick. Throughout this distance 'dreikanter' were common in the top 18 inches of soil and subsoil.

These wind-worn stones varied in size from small boulders 8 inches long to small pebbles. The majority were of quartzite and had assumed those forms usually associated with the term 'dreikanter'. Pebbles of less homogeneous constitution, such as grit, vein quartz, and various igneous rocks, were not as a rule faceted, but had that wavy, pitted, or undercut type of polished surface which is the characteristic effect of the sand-blast action of the wind and of insolation.

Further investigation shows that these wind-worn stones are not confined to the locality of Ramsdale, but are widely distributed over the whole district, on both Keuper and Bunter outcrops, from beyond Oxtun in the north to Wilford Hill and Clifton in the south. No