PALAEONTOLOGIA

AFRICANA

ANNALS OF THE BERNARD PRICE INSTITUTE FOR
PALAEONTOLOGICAL RESEARCH
UNIVERSITY OF THE WITWATERSRAND
JOHANNESBURG

VOLUME 15, 1973
PART 2

Palaeont. afr., **15**, 37–64. 1973

A REVIEW OF THE EVIDENCE FOR MARINE CONDITIONS IN SOUTHERN AFRICA DURING DWYKA TIMES

by

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CONTENTS

ABSTRACT

The faunas of the three major Dwyka basins in southern Africa are listed in the form of tables. Marine invertebrates have been recorded from the western part of the Kalahari basin and from the Warmbad basin, but had not previously been confirmed within the Great Karroo basin. A new fauna from the base of the Upper Dwyka shales near Kimberley is described. Cephalopods, brachiopods and lamellibranchs are found in calcareous concretions, which also contain palaeoniscoid fish, coprolites, fossil wood and the mineral glauberite. The marine invasion into South West Africa postulated by Martin & Wilczewski (1970) therefore extended into the Great Karroo basin as well. By the time of accumulation of the White Band at the top of the Upper Dwyka shales, conditions were probably non-marine; with the possible exception of the Notocarid crustaceans, the White Band fossils are not, in themselves, indicative of marine conditions. The only other significant indication of marine conditions in the Great Karroo basin is the glauconite in the deltaic Coal Measures of the Ecca in the northern part of the basin. It is possible then that the fossiliferous marine shales near Kimberley accumulated as a fine-grained offshore facies of the Ecca deltaic sequence.

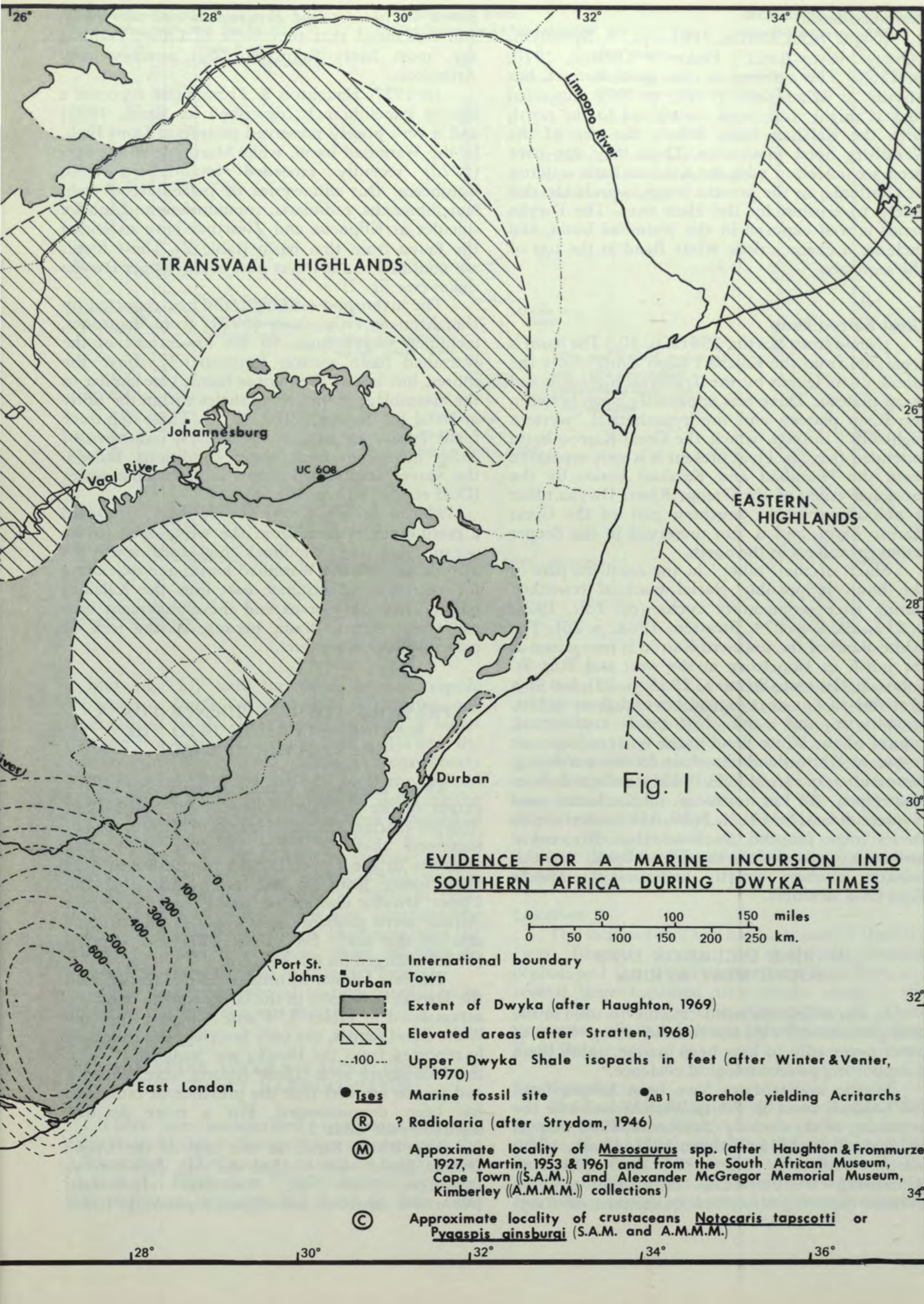
GENERAL GEOLOGY

The extent of the Dwyka sediments considered in this article is shown in fig. 1. Generalised stratigraphic sections of the three main basins are given in fig. 2. For the purpose of this discussion, the White Band is taken to mark the top of the Upper Dwyka Stage.

Kalahari Basin

(Name from Martin, 1961a, p. 15. Synonyms include: "South Kalahari basin", Martin, 1961a, table II, 1968, table 2, 1970, p. 225; "Kalahari Karroo basin", Green, 1969, fig. I; "Botswana block", Frakes & Crowell, 1970, p. 2263.) There are outcrops in South West Africa, the Gordonia area and eastern Botswana, the central portion of the basin being covered by Cenozoic Kalahari sediments. Green (1969, fig. I) illustrated the continuity of the Karroo strata between the eastern and western outcrops. The Dwyka series is well exposed in South West Africa, but in eastern Botswana it is poorly exposed and is of variable thickness and discontinuous development. A white-weathering unit at the top of the Dwyka sequence contains *Mesosaurus*, and is considered to be the equivalent of the White Band (du Toit, 1954, p. 329; Martin, 1961a, p. 34; Heath, 1966, p. 42)(see also fig. 1 and table 5). Coals occur below this horizon in the Upper Dwyka Stage (Martin, 1953; 1961a, p. 34).

WINDHOEK HIGHLANDS
KALAHARI BASIN
Botswana
South West Africa
Schlip
Hardap
Marienthal
Gaus
Asab
Viperstorf
Brukkaros
Ganikobis
Tses
Itzawisis
s.Wasser
Gellap
Keetmanshoop
Huns
Fish River
WARMBAD BASIN
Gordonia area
KAAP PLATEAU
Vryburg
Kanibeam
Klipneus
Haib
Warmbad
Zwartbas
Ham R.
Orange River
Blaauw Krantz
Kimberley
Douglas
Hopetown
Riet
Loeriesfontein
GREAT KARROO BASIN
Tankwa River
Laingsburg
WESTERN HIGHLANDS
Cape Town
South Africa



26°
28°
30°
32°
34°
Limpopo River
24°
TRANSVAAL HIGHLANDS
26°
Johannesburg
Vaal River
UC 608
EASTERN HIGHLANDS
28°
Durban
Fig. I
30°
EVIDENCE FOR A MARINE INCURSION INTO SOUTHERN AFRICA DURING DWYKA TIMES
0 50 100 150 miles
0 50 100 150 200 250 km.
0
100
200
300
400
500
600
700
Port St. Johns
32°
International boundary
Durban Town
Extent of Dwyka (after Haughton, 1969)
Elevated areas (after Stratten, 1968)
--100-- Upper Dwyka Shale isopachs in feet (after Winter & Venter, 1970)
East London
Tses Marine fossil site
AB 1 Borehole yielding Acritarchs
? Radiolaria (after Strydom, 1946)
Appoximate locality of Mesosaurus spp. (after Haughton & Frommurze 1927, Martin, 1953 & 1961 and from the South African Museum, Cape Town ((S.A.M.)) and Alexander McGregor Memorial Museum, Kimberley ((A.M.M.M.)) collections)
34°
Approximate locality of crustaceans Notocaris tapscotti or Pygaspis ginsburgi (S.A.M. and A.M.M.M.)
28°
30°
32°
34°
36°

Warmbad Basin

(Name from Martin, 1961a, p. 34. Synonym: "Orange River Basin", Frakes & Crowell, 1970, p. 2268.) This outcrop is now quite distinct, but Martin & Wilczewski (1970, p. 227) suggested that it might have been connected to the north with the Kalahari basin before the rise of the Karasberg horst mountains. There may also have been a connection with the Kalahari basin outcrop in Gordonia, as the present break is probably due solely to erosion by the Ham river. The Dwyka series is well exposed in the Warmbad basin, and includes a characteristic White Band at the top of the sequence.

Great Karroo Basin

(Name from Martin, 1961a, p. 30.) The basin is separated from the Kalahari basin along nearly the whole of its length by the Transvaal highlands and Kaap plateau. There was apparently a gap between the Kaap plateau and the hypothetical "western highlands" through which the Great Karroo basin extended (see fig. 1); at present it is only separated from the Warmbad and Kalahari basins by the erosional valley of the Orange River. Dwyka tillite is ubiquitous in the southern part of the Great Karroo basin, and is also preserved in the deeper basement valleys in the north.

Much of the "tillite" in the northern part of the basin is possibly glacial material reworked during later sedimentary cycles (du Toit, 1921, p. 217; 1954, p. 274; Stratten, 1968, p. 26). The White Band of the southern Karroo is recognised as far north as Hopetown in the west and Port St. Johns in the east (Stratten, 1968, p. 20), but it is probable that it does extend beyond these points. *Mesosaurus* spp. and Notocarid crustaceans, typical of the White Band in the western Cape, are found in White Band-like shale farther north; e.g. *Mesosaurus* sp. (A.M.M.M. 4431) collected from Kameelpan, 32 km north-east of Kimberley, and Notocarididae (A.M.M.M. 2689, 3689) from the de Beer's mine property in Kimberley. No coal is known to occur below the White Band, and this horizon nowhere directly underlies the Middle Ecca Coal Measures.

MARINE INCURSION INTO SOUTH WEST AFRICA

In this article the word "marine" is used in the biological sense; we do not consider a large body of water necessarily to have been marine, unless there is supporting palaeontological evidence.

Marine invertebrates have been known from the Kalahari basin in South West Africa since the beginning of the century (Schroeder, 1908; Range, 1912; du Toit, 1915; Dickins, 1961; Heath, 1966; Martin, Walliser & Wilczewski, 1970; Martin & Wilczewski, 1970; Wass, 1972.)(see table 1). Dickins (op cit.) described collections of *Eurydesma mytiloides* and *Peruvispira vipersdorfensis*, and concluded that they were of Lower Permian age, most likely Sakmarian, but possibly early Artinskian.

In 1927, Haughton & Frommurze reported a marine lamellibranch (described by Reed, 1935) and a very poorly preserved gastropod from Haib, in the Warmbad basin, while Martin & Wilczewski (1970) recently recorded foraminifera from Kanibeam. Our discoveries of palaeoniscoid fish, lamellibranchs, radiolaria, foraminifera and sponge spicules at Klipneus and Zwartbas have extended the fauna from that basin (table 2). These fossils are confined to the lower part of the Upper Dwyka shales (see fig. 2).

The arthropod walking trails first reported by Haughton & Frommurze (1927) from flagstones, including varved units, in the lower part of the Warmbad basin section (immediately above the tillites, but below the marine faunas) are similar to the assemblage from varved shales within the tillite in Natal (cf. Savage, 1970, 1971). These rich trace fossil faunas are not, in themselves, indicative of either marine or fresh water conditions. Indeed, the varves imply deposition in non-saline water (Duff et al., 1967, p. 50).

Martin & Wilczewski (1970, fig. 4) proposed a marine embayment from the west, open to the ocean from the Windhoek highlands south to include at least the Warmbad basin, and extending for an unknown distance east into the Kalahari basin. They did not extend the embayment into the Great Karroo basin because of the lack of palaeontological support.

PREVIOUS FOSSIL EVIDENCE FOR A MARINE INCURSION INTO THE GREAT KARROO BASIN

There have been various speculations on the extent of the sea that supported the South West African marine faunas. Haughton (1919, p. 10) suggested that "... the presence of marine mollusca in the Upper Dwyka of the South-West Protectorate leads to the supposition that the Upper Dwyka clastics of the Union [of South Africa] were probably laid down in an estuarine arm of the sea". Du Toit (1921) and Stratten (1968) enlarged on this concept.

The few known records of animal fossils from the Dwyka sediments in the Great Karroo basin are summarised in tables 3, 4 and 5. Apart from the White Band faunas, the only invertebrates previously reported from the Dwyka are "radiolaria" from the Laingsburg area. These reports were tentative and we do not feel that the presence of radiolaria has been demonstrated. For a more detailed discussion see table 3.

The White Band, at the top of the Upper Dwyka Shales, has yielded the fish *Palaeoniscus capensis* (table 4), Notocarid crustaceans (*Notocaris tapscotti* and *Pygaspis ginsburgi* [table

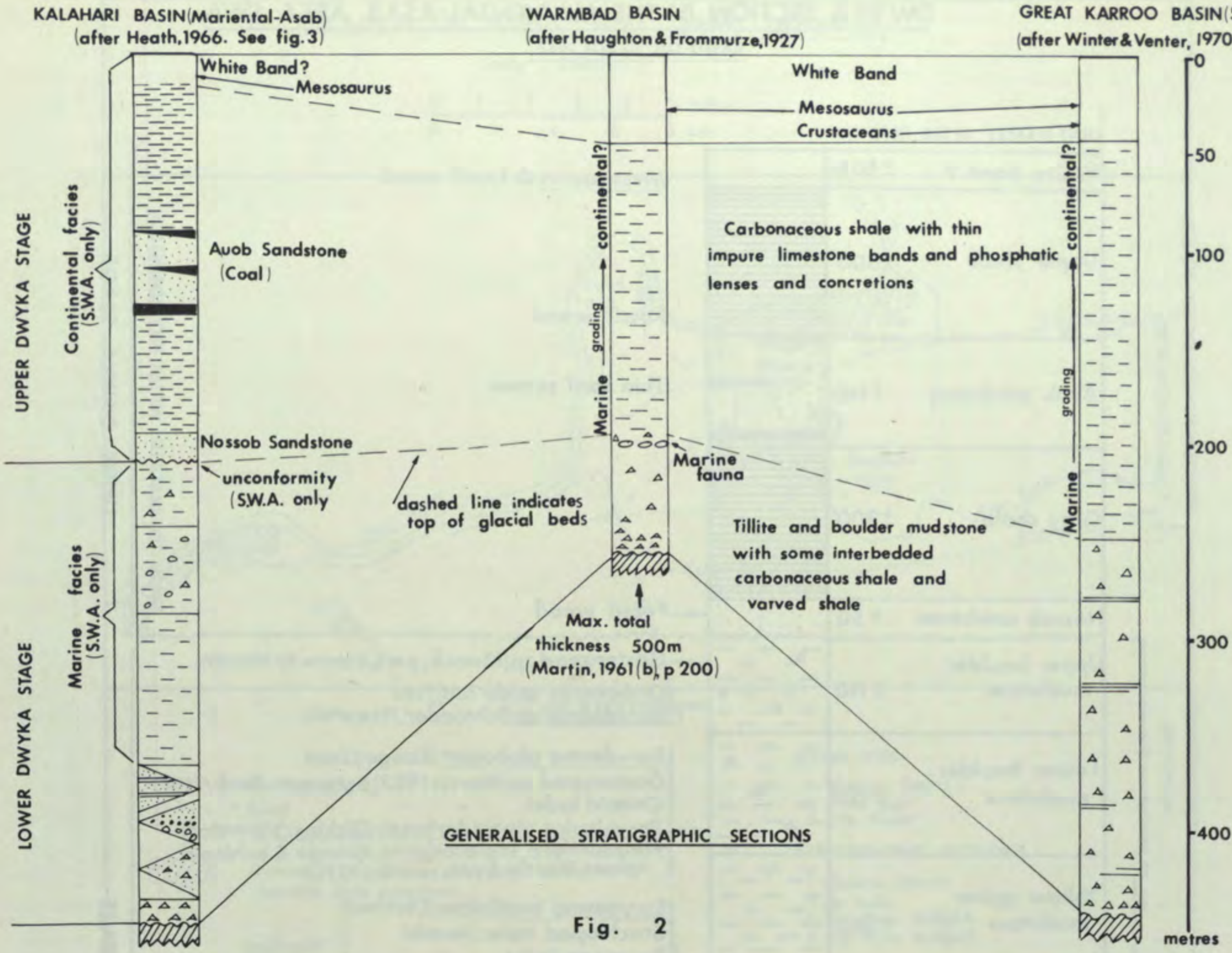


Fig. 2

3 and fig. 1]) and the small aquatic reptile *Mesosaurus* (table 5 and fig. 1). From our observations in the Loeriesfontein area, it seems that the fish occur in finely bedded shales near the base of the White Band, while the crustaceans occur in poorly bedded sediment near the top and *Mesosaurus* in a silty, bedded facies, also near the top of the unit. *Mesosaurus* has been regarded as both a non-marine (Holmes, 1965, p. 1222; Romer, 1966, p. 117) and a marine animal (Rayner, 1970, p. 475; Teichert, 1970, p. 132; Meyerhof & Meyerhof, 1972, p. 290). In isolation, the skeletal remains do not proclaim the salinity of the water inhabited. However, from the available associated evidence, there is little to suggest that the water was marine (see below).

Clear fossil evidence of marine conditions in the Great Karroo Basin was therefore lacking.

A MARINE DWYKA FAUNA FROM THE GREAT KARROO BASIN

There are undescribed specimens of the palaeoniscoid fish ? *Namaichthys schroederi* in the Alexander McGregor Memorial Museum (A.M.M.M.), Kimberley. The fish were collected by Robert Broom, in about 1940, from the farm Zand Bult near Douglas. They occur in concretions very similar to those containing marine invertebrates in South West Africa. We revisited Broom's site, and found that the concretions also contain marine invertebrates. More recently we discovered a second site near the Tankwa river (fig. 1) at the same stratigraphic position as the Zand Bult (Blaauw Krantz) locality. No invertebrates have yet been recognised, but wood, fish and coprolites are present. Only the Blaauw Krantz site is described in detail here.

Location

The richest fossil site has been named after the farm Blaauw Krantz. A single fragmentary cephalopod was found on the farm Zand Bult, and several large fossilised tree trunks occur in the shales on the farm Olie Rivier (fig. 4). These properties are subdivisions of the original farm Zand Bult.

Stratigraphy

Du Toit (1915, pp. 44–45) noted that "The Dwyka in South West Africa is more or less a replica of that obtaining along the strip of country extending from Vryburg to Prieska, and the conditions which prevailed during its deposition in the former region appear to have extended up this

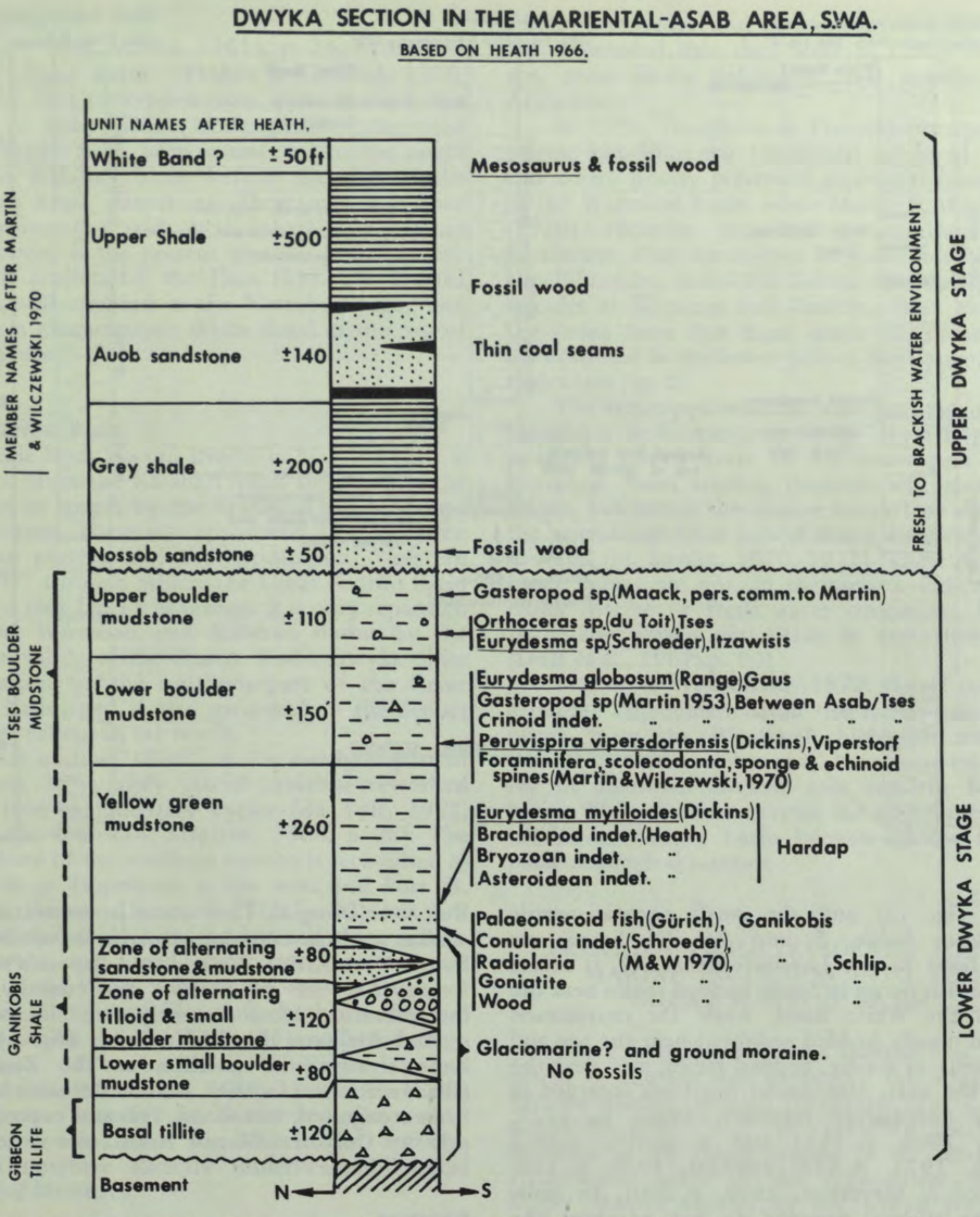


Fig. 3. It is not clear how the member names used by Martin & Wilczewski 1970 apply to the units mapped by Martin 1953, or Heath 1966. Martin (written comm. 1973) says that the three glaciomarine units thin towards the south until the Ganikobis shale comes to rest on the basal tillite.

pre-Karroo depression to which I have given the name of the Kaap Valley."

Fresh exposures near Douglas are largely confined to the banks of incised rivers. A composite section (fig. 5) has been compiled from four locations (see fig. 4) near the Blaauw Krantz fossil site. Unfortunately, the strata between the sections are obscured by recent sediments, and their relative vertical placings had to be made on lithological similarity and projected geology.

The basement in the area is formed of Precambrian Ventersdorp lava that possessed a moderate relief at the time of Dwyka accumulation. As the basement does not outcrop at any of the sections measured, the total thickness of the Dwyka tillite could not be determined. It is likely to vary considerably due to the uneven nature of the basement. The top of the Dwyka tillite has been put at the level of the highest dropstone-bearing bed, giving an approximate thickness of

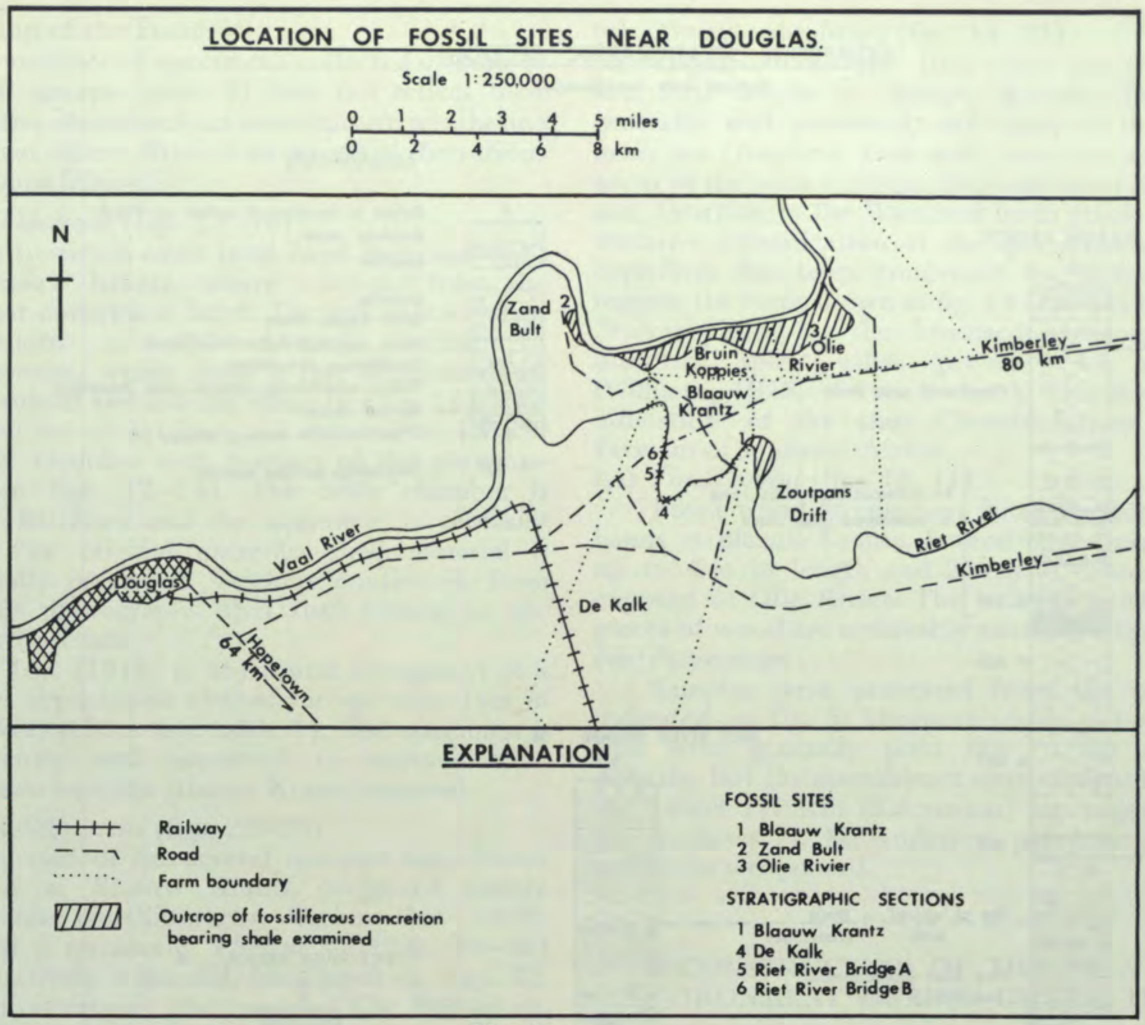
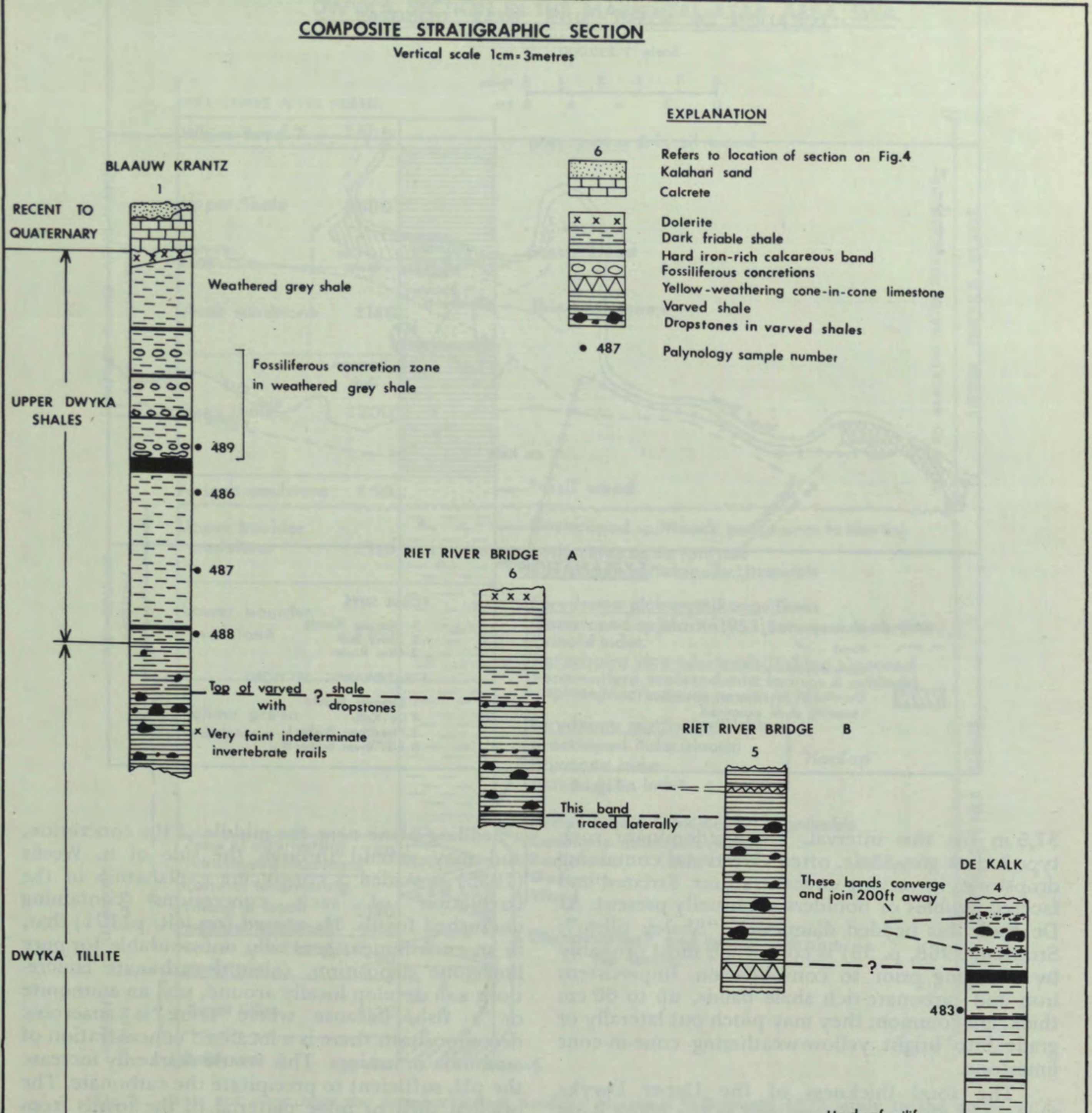


Fig. 4

37,5 m for this interval. The predominant rock type is dark grey shale, often varved and containing dropstones in varying concentrations. Striated and faceted pebbles or boulders are usually present. At De Kalk this bedded diamictite ("Shaley tillite": Stratten, 1968, p. 33) is contorted, most probably by slumping prior to consolidation. Impersistent iron and carbonate-rich shale bands, up to 60 cm thick, are common; they may pinch out laterally or grade into bright yellow-weathering cone-in-cone limestone.

The total thickness of the Upper Dwyka Shales has not been determined as the White Band does not outcrop near the fossil sites. The section is directly overlain by a variable thickness of calcrete-cemented Quaternary sediments, topped by red Kalahari sand (figs. 5, 9). At Blaauw Krantz, approximately 18 m of dark grey splintery shale is exposed. A dolerite sill intrudes the upper portion of the shale. A 6 m zone containing calcareous fossiliferous concretions lies 9 m above the base of the shales. The concretions occur in bands at four levels. They protrude from the softer shale, and are concentrated in small gullies by erosion. Their shape is commonly oval and flattened, but in the lowermost band they are frequently irregularly lobed. When fossils are present, they usually lie on a bedding plane near the middle of the concretion, and may extend through the side of it. Weeks (1935) provided a convincing explanation of the formation of such concretions containing uncrushed fossils. He argued (op. cit. p. 171) that, in an environment generally unfavourable for pure limestone deposition, calcium carbonate concretions can develop locally around, say, an ammonite or a fish, because where there is anaerobic decomposition there is a localized concentration of ammonia or amines. This would markedly increase the pH, sufficient to precipitate the carbonate. The original shell or bone material of the fossils from Blaauw Krantz is sometimes preserved but, more usually, it has been removed by solution and replaced by crumbly yellow limonite.

An interesting feature is the occurrence of hollow moulds of crystals (approximately 10 cm long and 2–3 cm wide) in some of the concretions. The crystal casts were identified by Loock as being of the monoclinic salt glauberite ($Na_2SO_4 . CaSO_4$). Glendonites, which are calcitic pseudomorphs after glauberite, have been described from very much the same stratigraphic position in Permo-Carboniferous sediments in New South Wales (David et al., 1905), Queensland and Tasmania (Raggatt, 1937).



COMPOSITE STRATIGRAPHIC SECTION
Vertical scale 1cm=3metres
EXPLANATION
6 Refers to location of section on Fig.4
Kalahari sand
Calcrete
Dolerite
Dark friable shale
Hard iron-rich calcareous band
Fossiliferous concretions
Yellow-weathering cone-in-cone limestone
Varved shale
Dropstones in varved shales
• 487 Palynology sample number
BLAAUW KRANTZ
1
RECENT TO QUATERNARY
Weathered grey shale
Fossiliferous concretion zone in weathered grey shale
UPPER DWYKA SHALES
489
486
487
488
Top of varved shale with dropstones
Very faint indeterminate invertebrate trails
DWYKA TILLITE
RIET RIVER BRIDGE A
6
RIET RIVER BRIDGE B
5
This band traced laterally
DE KALK
4
These bands converge and join 200ft away
483
Hard unfossiliferous carbonate nodules
484
485
Folds of amplitude 10ft caused by slumping

Fig. 5

Description of the Fossils

The number of specimens collected of each of the fossil groups (table 3) does not reflect their true relative abundance, as some survive weathering better than others. Brief descriptions of the various fossil groups follow:

(i) *Cephalopods* (figs. 12–16)

One specimen came from Zand Bult, and eight from Blaauw Krantz, where most are from the lowermost concretion band. The specimens consist of portions of the external moulds of phragmacones, which show a fine ornamentation of longitudinal and annular striae (see fig. 15). Two specimens are of internal and external moulds of the body chamber with portion of the phragmacone (see figs. 12–14). The body chamber is strongly flattened and the siphuncle is centrally placed. The original nacreous shell material is occasionally preserved. Teichert confirmed, from stereopair photographs, that they belong to the order Orthocerida.

Du Toit (1915, p. 45) found a fragment of a nautiloid cephalopod *Orthoceras* sp. near Tses in South West Africa (see table 1). The specimen is insufficiently well preserved to warrant close comparison with the Blaauw Krantz material.

(ii) *Lamellibranchs* (figs. 22–26)

Only two of the several hundred concretions examined at Blaauw Krantz contained clearly recognisable lamellibranchs. Dickins has kindly identified a nuculanid, *Phestia* sp. (figs. 24–26) and, tentatively, a nuculid, *Nuculopsis* sp. (figs. 22, 23) from stereopair photographs. The *Phestia* sp. apparently belongs to the *P. darwini* group of species "... which are fairly widespread in the Lower Permian, although similar shells also appear to be present in the uppermost Carboniferous." (Dickins, 1972, written comm.)

(iii) *Brachiopods*

Only one concretion, (I.40), yielded brachiopods. They occur as external casts. Dickins, using the specimens and latex casts, has identified them as *Attenuatella* sp. The genus is apparently confined to the Permian, and occurs in New Zealand, Australia, North America and the U.S.S.R.

(iv) *Fish* (fig. 27)

Fish remains are relatively common. Scales and the larger skeletal elements, especially the skull, are often well preserved and undistorted. Jubb has identified the Kimberley museum specimens as most probably being *Namaichthys schroederi*. This species occurs in similar deposits in the Warmbad and Kalahari basins (table 4). It appears from the association of this species with marine invertebrates at the same horizon at Blaauw Krantz that the fish lived in a marine environment for at least part of its life. This is supported by the presence in two of the concretions (nos. P2 and P6) from Zwartbas, in the Warmbad basin, of *N. schroederi* with arenaceous foraminifera exposed in the matrix (see table 2).

(v) *"Spiral coprolites"* (figs. 18–21)

Together with the fish, these are the most abundant fossils at Blaauw Krantz. They are generally well preserved, and many of the specimens are complete. Less well preserved examples occur in the same stratigraphic position at Klipneus and Zwartbas in the Warmbad basin (table 4). Our tentative identification of the specimens as spiral coprolites has been confirmed by Williams. He regards the form shown in fig. 18 (I.20) as being an "enterospiron" or the fossilised contents of an intestinal spiral valve, probably of a shark (Williams, 1973, written comm.). This is the first indication of the class Chondrichthyes in the Permian of southern Africa.

(vi) *Fossil wood* (figs. 10, 11)

Fossil wood is common in all the concretion bands at Blaauw Krantz. Several large tree trunks, up to 4 m in length and 25 cm in diameter, are exposed at Olie Rivier. The ends of most of the pieces of wood are noticeably rounded (fig. 11).

(vii) *Palynology*

Samples were processed from the positions indicated on fig. 5. Miospore yields and preservation were generally poor due to the adjacent dolerite, but the assemblages were compatible with the Lower Permian (Sakmarian) age suggested by the molluscs (J. M. Anderson, pers. comm.). No acritarchs were noted.

RECONSTRUCTION OF THE PALAEO-ENVIRONMENT DURING DWYKA TIMES

Tillite Stage

Stratten (1968) considered that the tillite in the south represents a ground moraine of terrestrial origin. In the north-west, from Loeriesfontein to Vryburg, the glacial sediments are bedded, indicating subaqueous deposition, but whether or not the water body was marine has not yet been established. Intercalated varves occur within the tillite in the southern Karroo (Stratten, 1968, p. 111), at the Douglas fossil sites and also in valleys in the northern Karroo basin (Cousins, 1950, p. 233; Hunter, 1969; Savage, 1971, p. 217). These were probably accumulated in fresh water; the development of varves is apparently inhibited by saline conditions, due to flocculation of the clay particles (cf. Pettijohn, 1957, p. 163; Duff et al., 1967, p. 50)(Hälbich, 1958, pp. 119–121; Rowsell, 1969, pp. 77–81 notwithstanding). Acanthomorphitae acritarchs (15–30 microns in diameter) have been recovered from shale intercalations in the lower 200 m of tillite in the southern Karroo boreholes (OL, SA, VR) shown in fig. 1 (J. M. Anderson, in prep.). Without supporting evidence, they should not be taken to indicate marine conditions. Shaley bands at several positions within the tillite stage in the southern Karroo and in pre-Dwyka valleys farther north (borehole U.C. 608)(J. M. Anderson, pers. comm.) and near Douglas (see fig. 5) have yielded moderately abundant miospores and coarse cuticular material. This suggests that vegetation was established within the Karroo basin during the period of glaciation, and supports the evidence, summarised by Plumstead (1969, p. 34), of leaf and stem remains within the glacial sediments.

The Kaap valley (Vryburg–Douglas, see p. 5) was probably occupied by a large glacier which originated on the Transvaal highlands and the Kaap Plateau. The western side of the valley rises sharply to a prominent scarp.

Marine Horizon at the Base of the Upper Dwyka Shales Stage

With the final retreat of glaciation, du Toit (1921, p. 215) envisaged the development of "... an immense estuary ... covering practically the whole area south-west of a line drawn from Mariental, past ... Vryburg to Port St. Johns; it connected with the ocean on the west and was presumably bounded by land on the south—certainly on the north and east." Stratten (1970, p. 488) postulated two restricted openings to the ocean, one in the north-west near Loeriesfontein, the other in the south-east, near East London.

The Douglas fauna provides the first clear evidence of marine conditions in the Great Karroo basin at that time. The marine character of the deposits at Blaauw Krantz gains further support from the occurrence of moulds of the mineral glauberite in concretions from the fossil-bearing horizons. David et al. (1905, p. 178) concluded that in Australia "The horizons ... being not far below ... the top of the highest beds of a Marine Series, where they are about to give place to fresh water beds ..., it is likely that the conditions favoured isolation of shallow sea basins ...". Raggatt (1937, p. 346) emphasised that cold marine conditions favoured the development of glauberite. He suggested that the decomposition of marine organisms might have provided the necessary sulphur. If the water were saturated with calcium carbonate, a slow warming, following the crystallisation of the glauberite, would induce precipitation of the carbonate. It would tend to accrete around a nucleus, perhaps a glauberite crystal or a cadaver, and so form concretions. Weeks (1953, p. 166) felt that for the formation of concretions, bottom conditions should be stagnant and anaerobic. The scarcity of bottom dwellers (brachiopods and lamellibranchs) at Blaauw Krantz supports this idea.

According to Stratten (1970, p. 488) "The Main area covered by this sea during the Dwyka Period is shown by the occurrence of the Upper Dwyka Shales" (see fig. 1). It is likely that the sea responsible for this fine-grained facies, which contains marine invertebrates at its base, extended farther north into the basin. This leads to speculation on the equivalent near-shore shallow-water facies. The most obvious other indicator of marine conditions in the Great Karroo basin is the glauconite associated with the Coal Measures in the deltaic Middle Ecca sediments of the northern part of the basin. A marine origin for this glauconite has always been in doubt, as the fossil evidence has been sparse and ambiguous (McLachlan, 1973). It is not impossible that the shales of the Douglas fossil sites were accumulating in the deeper water of a shallow shelf sea (linked to the ocean in the west), while the glauconite was formed during brief local transgressions of the sea on to the brackish/fresh-water coastal swamps where coal was accumulating i.e. that the White Band might be stratigraphically higher than the Middle Ecca coals. The few recorded "marine" fossils of the Ecca Coal Measures (sponge spicules, a problematic cephalopod, acritarchs) have seemed anomalous in a basin that lacked any typical marine macrofaunal assemblages (McLachlan, 1973). They too might have occurred in a marginal marine environment connected with brief transgressions of this sea. The facies distribution in the Kalahari basin is essentially the same: marine Dwyka in the west and a deltaic sequence with Coal Measures in the east, which are traditionally considered to be younger (i.e. Ecca). Du Toit (1954, p. 354) pointed out that in South America "The Rio Bonito group contains coal and has yielded an abundant flora ... strikingly like that of the Ecca series." Palynological studies may support this contention (J. M. Anderson, in prep.). In the Great Karroo basin, the coals occur in the northern portion of the basin, and the White Band (demarcating the top of the Upper Dwyka shales) in the southern portion, and no single section has been found to include both. In South America, however, the coal lies *below* the *Mesosaurus*-bearing zone (White Band equivalent) (cf. du Toit, 1954, p. 355). This is also the case in South West Africa (see p. 37).

The common occurrence of fossil wood at the Douglas sites certainly indicates a well established flora, including large trees, on the nearby land. The well-rounded ends (see fig. 11) of many of the pieces of wood probably formed during stream transport down the Kaap valley to the site of their deposition, which may have been estuarine.

White Band at the Top of the Upper Dwyka Shales Stage

Venter (1969, p. 15) and Stratten (1970, p. 488) believed that the Upper Dwyka Shales accumulated under marine or estuarine conditions. Fossil evidence is lacking for the greater part of the shales, and that from the White Band is inconclusive: the fish *Palaeoniscus capensis* confirms only that the environment was aqueous, and the aquatic reptile *Mesosaurus* gives no indication of the salinity of the water. The crustaceans might, however, be cited in support of marine deposition as "There is no positive evidence that any of the eocarids actually inhabited fresh water" (Brooks, 1964, R337). They were benthonic creatures and "... the crab-like *Notocaris*, from the Permian of Africa, is the culmination of this adaptive trend." (op. cit.). The existence of this bottom fauna does suggest that the strongly reducing conditions inferred from the White Band lithology were confined to the sediment itself, and the overlying water was perhaps not markedly de-oxygenated. The absence of other benthonic organisms is puzzling.

It is interesting that both the crustaceans and *Mesosaurus* have only been collected from the western side of the Great Karroo basin (fig. 1). The isopachs of the Upper Dwyka Shales show separate eastern and western sub-basins (Winter & Venter, 1970, fig. 6), and it may be that conditions in the east were different at the time of deposition of the White Band. It is also likely that fossils have not been noted in the White Band east of Laingsburg because they have been obscured by the metamorphic effects of the Cape folding. A further point on the distribution of these fossils is their occurrence at positions ranging from near the zero isopach at Kimberley to the 600 ft. (183 m) isopach in the western Cape.

Fossil wood and leaves have been recorded from several localities in the White Band (Haughton et al., 1953, p. 23; du Toit, 1954, p. 279; Hälbich, 1958, p. 124; Heath, 1966, p. 42). In the western Kalahari basin the White Band is separated from the marine faunas by nearly 350 m of sediment and an erosional unconformity (Heath, 1966, Pl. 1, p. 73), while the glauberite in the marine horizon at Blaauw Krantz indicates that conditions were becoming less saline from the base of the shales upwards (see above). The turbidite beds in the overlying Ecca sediments (Kuenen, 1963, pp. 191–192; Ryan, 1967, p. 953; 1968, p. 133; Theron, 1967; Truswell & Ryan, 1969) have been quoted in support of a marine environment for the White Band (Meyerhof & Meyerhof, 1972 p. 290), but the White Band itself is not known to contain turbidites and, furthermore, turbidity currents are not exclusively operative in saline water (cf. McBride, 1964, p. 94).

CONCLUSION

The fauna at Douglas confirms the existence of marine conditions in at least the western part of the Great Karroo basin and links it to the sea that occupied the Warmbad basin and the western Kalahari basin at the close of Dwyka glaciation. The marine invasion was apparently brief, and by White Band times conditions were possibly already non-marine, perhaps due to elimination of the connection with the ocean in the west.

ACKNOWLEDGEMENTS

We thank Dr. J. M. Dickins, Dr. C. Teichert, Dr. R. A. Jubb, Dr. M. E. Williams and Mr. J. C. Loock for specimen identifications, Mr. J. M. Anderson for allowing reference to his palynological data, and Dr. H. Martin for commenting on the geological section in the Kalahari basin in South West Africa.

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TABLE 1

DWYKA INVERTEBRATE FAUNA–KALAHARI BASIN IN SOUTH WEST AFRICA

For place names, see 1:1,000,000 geological map of South West Africa (1963).

Geological Unit	SITE	FOSSILS	AVAILABLE SPECIMEN DETAILS	SOURCE
Tses Boulder–Mudstone	Gaus and Itzawisis	Lamellibranch: *Eurydesma cf. globosum* re-allocated to *E. mytiloides* by Dickins (1961, p. 143) Gastropod, indet.	Numerous. In dark shales above glacial tillite.	Schroeder (1908, p. 695) identified specimens found by Range at Itzawisis. Range (1912, p. 29) recorded *E. cf. globosum* from the farm Itzawisis, and from Gaus, on the Kameelhaar river. Von Huene (1925, p. 27) listed *Eurydesma* and *Conularia* from Itzawisis and Gnus (? misquoting Range, 1912).
	Gellap and s. Wasser	Lamellibranch: *Eurydesma mytiloides*	From turbidite sandstone interbedded with shale.	Martin & Wilczewski (1970, p. 226), name only.
	Huns	Lamellibranch: *Inoceramus*-like bivalve Gastropod, indet.	'steinkern', isolated specimens	Range (1912, p. 30). Tentative identification only. No figure. The position of this site, on Huns farm, 13 miles S.E. of Keetmanshoop, appears to fall within the Tses Boulder-mudstone (from Martin, 1953, Pl. 5). Range (1912) records the fossils also from Gibeon.
	Viperstorf and Tses	Gastropod: *Peruvispira vipersdor-fensis*	Several hundred, but only 4 good enough to describe. In calcareous concretions. (Geological Survey, Pretoria)	Dickins (1961) described and figured 4 specimens from the farm Viperstorf 63. He also mentioned 'other specimens' from 8 miles West of Tses siding, near the main road.
	Tses	Nautiloid cephalopod: *Orthoceras* sp.	Single fragmentary specimen in a concretion. External and internal moulds of portion of phragmacone 5 cm long. (South African Museum, Cape Town, No. 8931.)	Du Toit (1915, p. xlv), name only. Du Toit (1921, p. 214), name only. Haughton & Frommurze (1927, p. 142), brief description, no illustration.
	Brukkaros	Echinoid remains *Archaeocidaris* sp.	Fragmentary ambulacral plates and spines. In a calcareous concretion.	Haughton & Frommurze (1927, p. 141), brief description, no illustration, from W. of Brukkaros siding, near the main road.
	Locality unspecified	Echinoid remains: spines Sponge spicules Scolecondonts	In calcareous concretions.	Martin & Wilczewski (1970, p. 226), listed only.
	Between Asab and Tses	Crinoid columns Gastropod, indet.	In calcareous concretions.	Martin (1953, p. 37), mentioned only. Martin & Wilczewski (1970, p. 226), mentioned only the crinoid columns.
	Tses	Foraminifera: genera *Hyperammina, Ammodiscus, Glomospira, Ammobacculites, Spiroplectammina.*	In calcareous concretions, from 2 localities near Tses, close to one another.	Martin & Wilczewski (1970, pp. 226–227) reported. Identifications not yet completed.

Ganikobis Shale	Schlip	Cephalopod: Goniatite genus *Eosianites*, subgenus *Glaphyrites*.	A single specimen, complete and well preserved. In a siliceous, phosphatic concretion. (Geological Survey, Windhoek)	Martin, Walliser & Wilczewski (1970), described and figured (line drawing).
		Radiolaria, indet.	In siliceous, phosphatic concretions.	Martin, Walliser & Wilczewski (1970, p. 621), mentioned only.
	Hardap 110	Lamellibrach: *Eurydesma mytiloides*	At least 5 moderately well-preserved specimens. In sandstone turbidite beds. (Geological Survey, Pretoria)	Martin (1953, p. 37), mentioned only. Dickins (1961) described and illustrated.
		Gastropod, indet.	One specimen. In fine grained sandstone. With bryozoan fragments.	Wass (1972, p. 871), mentioned only.
		Brachiopod, indet.	In sandstone turbidites, intercalated in shales. Identified by Dr. Glaessner.	Heath (1966, p. 30, Pl. XVII).
		Bryozoa, indet. Later identified as *Dyscritella cf. D. spinigera* (Bassler)	In sandstone turbidites, intercalated in shales.	Martin & Wilczewski (1970, p. 226), listed. Dickins (1961, p. 138). Mentioned only. Wass (1972), described, illustrated, named.
		Asteroidean, family Monasteridae. Genus and species indet.	Single arm only. Associated with *Eurydesma mytiloides* and bryozoan fragments. (United States National Museum collections. No. 16259).	Lane & Frakes (1970). In the Fish River valley, a few km N.W. of Mariental i.e. within 10 km of Hardap 110.
		Asteroidean, indet.	Occur in sandstone turbidites interbedded with shale. According to Martin (pers. comm.) the specimens (in the Windhoek Museum) have been lost.	Martin & Wilczewski (1970), listed one. Heath (1966, p. 30, Pl. XVIII) found a specimen in his "yellow-green mudstone" zone.
	Mariental, E. of railway station	Lamellibranch: *Eurydesma globosum*	In sandstone and shale, together with worm burrows and Phyllotheca-like stems.	Du Toit (1916, p. 11), mentioned only. Heath (1966, p. 30) concluded that they derived from the same zone as the fish at Ganikobis i.e. Ganikobis shale.
	Ganikobis	Gastropod, indet.	Single specimen. In siliceous concretion.	Martin & Wilczewski (1970, p. 226), listed.
		Conularia sp.	Single specimen. In siliceous concretion.	Schroeder (1908, p. 697) reported. Range (1912, Fig. 3), illustrated.
		Radiolaria, indet.	In siliceous concretions.	Martin & Wilczewski (1970, p. 226), listed.
Locality unknown		Brachiopod: *Productus* sp.	No details.	Von Huene (1925, p. 27) noted a *Productus* in Dr. Reuning's collection.

TABLE 2

DWYKA INVERTEBRATE FAUNA–WARMBAD BASIN, SOUTHERN SOUTH WEST AFRICA

For location of sites, see 1:250,000 geological sheet Amib (H-33-F) in Haughton & Frommurze (1936).

Geological Unit	SITE	FOSSILS	AVAILABLE SPECIMEN DETAILS	SOURCE
Lower part of Upper Dwyka Shale	Haib	Lamellibranch: *Aphanaia haibensis*	2 specimens, one being very poor and fragmentary. (Probably housed in the South African Museum, Cape Town. (S.A.M.).)	Reed (1935), described and figured.
		Gastropod, indet.	1 specimen, a coiled shell, too poor for any satisfactory identification. (Probably S.A.M.)	Reed (1935, p. 161), discussed. No. illustration.
	Kanibeam	Arenaceous foraminifera: almost identical with those from Tses, Kalahari basin.	In calcareous concretions. Extracted by acid treatment. No further information. (Martin 1971, written comm.)	Martin & Wilczewski (1970, p. 227). Mentioned only.
	Klipneus	Lamellibranch, indet.	2 poor internal moulds, in a calcareous concretion. (Bernard Price Institute for Palaeontological Research (B.P.I.P.R.) I.41.)	
		Arenaceous foraminifera Radiolaria Sponge spicules.	In calcareous concretions from fossil fish horizon. Extracted by acid treatment. (B.P.I.P.R.)	Recently collected by the authors. Investigation proceeding.
	Zwartbas	Lamellibranch, indet.	1 specimen, external mould, in a calcareous concretion. (B.P.I.P.R. I.43)	
		Arenaceous foraminifera.	4 specimens visible in 2 calcareous concretions also containing fish. (B.P.I.P.R. P.2 and P.6)	

Heavy lines indicate new finds.

TABLE 3

DWYKA INVERTEBRATE FAUNA–GREAT KARROO BASIN, SOUTH AFRICA

Geological Unit	SITE	FOSSILS	AVAILABLE SPECIMEN DETAILS	SOURCE
White Band	Kimberley area	Crustacean: subclass: Eumalacostraca superorder: Eocarida order: Pygocephalomorpha family: Notocarididae *Notocaris tapscotti*	Numerous specimens. Impressions in weathered White Band. (A.M.M.M.* and Albany Museum, Grahamstown.)	Rogers & du Toit (1909, p. 193): "probably *Anthrapalaemon* sp.", listed from the Upper shales. Haughton (1919, p. 9) ". . . provisionally assigned to the Carboniferous genus *Anthrapalaemon* by Reed, in the White Band at the boring at Elandsdraai, Orange River Station". Woods (1922) described and figured *Pygocephalus* sp., from near Kimberley. Broom (1931) described and figured better material from Woods' (1922) site, and renamed the fossil *Notocaris tapscotti*. du Toit (1954, p. 279) listed "*Notocaris (Pygocephalus) tapscotti* Broom, Kimberley, and *Anthrapalaemon* sp., Orange River Station" (near Hopetown) from the White Band. Haughton (1969, p. 355): "From Kimberley . . . *Notocaris tapscotti* and from Orange River Station another Crustacean *Anthrapalaemon* sp." *Pygaspis ginsburgi* Fabre not mentioned. Brooks (1969, p. R341): "*Anthrapalaemon* is believed to be a synonym of *Pygocephalus*". We conclude, therefore, that the names *Anthrapalaemon* sp., *Pygocephalus* sp. and *Notocaris tapscotti* probably refer to identical crustaceans from the White Band in the Kimberley–Orange River Station vicinity, and that *Notocaris tapscotti* is the only valid name. Its relationship to *Pygaspis ginsburgi* from the White Band at Laingsburg has not yet been established by direct comparison.
	Loeriesfontein area	Crustacean: family: Notocarididae	Numerous specimens. Impressions in weathered White Band. (S.A.M.*, B.P.I.P.R.* and Stellenbosch University.)	Recently collected from the farm Ezels Fontein.
	Laingsburg	Crustacean: family: Notocarididae *Pygaspis ginsburgi*	Numerous specimens. Impressions in White Band. (S.A.M. and B.P.I.P.R.)	Fabre (1967), described and figured. He did not re-examine *Notocaris tapscotti*.
	Small crustaceans also occur in the Iraty Formation in Brazil. The Iraty Formation is considered to be the equivalent of the White Band (du Toit, 1954, p. 353). Bigarella and Salamuni (1967, pp. 64–65) list *Pygaspis braziliensis, P. quadrata, Paulocaris pachecoi, Clarkecaris brazilicus, Liocaris huenei* and *L. augusta*.			
Upper Dwyka Shales	Sambokkraal borehole	Sponge? spicules		Haughton *et al.* (1953, pp. 22, 40) mentioned "spicules, presumably from sponges" from a calcareous, carbonaceous shale, some 110 feet (34 m) below the base of the White Band.

Base of the Upper Dwyka Shales	Matjiesfontein	Radiolaria	5 specimens figured from a single thin section of phosphorite rock (Slide stored at Stellenbosch University, Geology Department. Apparently now lost.)	Strydom (1964, p. 279, Pl. II), briefly described and illustrated. Judging from the photographs and descriptions, it is possible that the "radiolaria" might, in fact, have been spinose acritarchs.
Matjiesfontein chert, in the Lower Ecca Shales	Laingsburg	Radiolarian spicules	"Probable radiolarian spicules occur in the cherty textured part of the graded interval" of the Matjiesfontein chert member, which is a turbidite sequence. *It lies within the Lower Ecca series,* a few feet above the White Band.	A. C. Theron (1967, pp. 15, 22), mentioned. (See forgoing quote.) Both Mr. A. C. Theron and his M.Sc. supervisor Prof. I. C. Rust (1972, written comms.) stress that the identification was extremely tentative. A. C. Theron (1967, p. 15) erroneously referred Strydom's (1964) "radiolaria" to his Lower Ecca Zoutkloof shale member, immediately above the White Band. Teichert (1970, p. 132): "... the 'White Band', which contains Radiolaria and is overlain by a radiolarian chert (J. N. Theron, pers. comm.)". Dr. J. N. Theron (1972, written comm.) states that Teichert (1970) misquoted him. Rust and A. C. Theron (1972, written comm.) confirm that there has been no report of Radiolaria in the White Band.
Base of the Upper Dwyka Shales	The sites near Douglas	Lamellibranchs: (i) Nuculid? ? *Nuculopsis* sp.	1 complete specimen, internal and external moulds, in a calcareous concretion. (B.P.I.P.R. I.39) (see figs 22, 23).	Recently collected by the authors. Dr. J. M. Dickins made identifications from stereopair photographs.
		(ii) Nuculanid *Phestia* sp.	Complete specimen, internal and external moulds, and 2 other partial external moulds, all in a single calcareous concretion. (B.P.I.P.R. I.38) (see figs 24, 25, 26).	
		Brachiopod: *Attenuatella* sp.	Several specimens, internal moulds, all in a single calcareous concretion. (B.P.I.P.R. I.40).	Recently collected by the authors. Dr. J. M. Dickins made the identitification from the specimens themselves.
		Orthocerid cephalopods: (i)	8 specimens in calcareous concretions. Most are external moulds, 2 of which are nearly complete. 2 specimens show internal and external moulds of the body chamber (figs. 12, 13, 14). Septa are occasionally present. The siphuncle is central. (B.P.I.P.R. I.1–I.8). One incomplete specimen was found at Zand Bult. External and internal mould of part of phragmacone.	Recently collected by the authors. Identification confirmed by Dr. C. Teichert, from stereopair photographs.
		(ii)	1 incomplete specimen in a calcareous concretion. External mould of portion of phragmacone. Septa and siphuncle partially preserved. (B.P.I.P.R. I.9) (see fig. 16).	

* A.M.M.M. = Alexander McGregor Memorial Museum, Kimberley.
S.A.M. = South African Museum, Cape Town.
B.P.I.P.R. = Bernard Price Institute for Palaeontological Research, Johannesburg.

Heavy lines indicate new finds.

TABLE 4

DWYKA FISH FROM THE KALAHARI, WARMBAD AND GREAT KARROO BASINS

BASIN	Geological Unit	SITE	FOSSILS	AVAILABLE SPECIMEN DETAILS	SOURCE
KALAHARI BASIN	Ganikobis Shale	Schlip	Palaeoniscoid fish, indet.	In siliceous concretions	Martin & Wilczewski (1970). Mention only.
		Ganikobis	Palaeoniscoid fish: (a) *Namaichthys schroederi*	7 specimens in calcareous concretions. Holotype lost. (Neotype at Geological Survey, Pretoria, others at British Museum of Natural History.)	Gürich (1923) described and illustrated *Namaichthys schroederi.* Gardiner (1962) re-described and figured new material.
			(b) *Watsonichthys lotzi*	1 specimen of incomplete fish. (Original material at Central Geological Service, Berlin. Presumed lost.)	Gürich (1923) described and illustrated *Acrolepis lotzi.* Gardiner (1962) renamed.
			(c) *Elonichthys?* (d) *Rhadinichthys?* (e) Genus V		Gürich (1923) described and illustrated.
WARMBAD BASIN	Base of Upper Dwyka Shales	Haib	Fish scales, indet.	In concretions. Also a "fragment of a large amphibian (?) bone". No further details.	Haughton & Frommurze (1927, p. 141). Mention only.
		Viool's Drift	Palaeoniscoid fish fragments "assigned to the genus *Acrolepis*".	In concretions.	Haughton & Frommurze (1927, p. 141). Mention only.
		Klipneus**	Palaeoniscoid fish, indet.	3 specimens in calcareous concretions and a number of isolated scales in individual concretions. (B.P.I.P.R.* P.7–P.10.)	Recently collected by the authors.
		Zwartbas**	Palaeoniscoid fish: *Namaichthys schroederi?*	6 specimens in calcareous concretions. (B.P.I.P.R. P.1–P.6.)	Dr. R. A. Jubb made identifaction from specimens recently collected by the authors.
		Ezels Fontein, farm near Loeriesfontein	Palaeoniscoid fish, indet.	Several specimens. Impressions only. (S.A.M.*, Stellenbosch University, B.P.I.P.R.)	B.P.I.P.R. specimens collected recently. Dr. R. A. Jubb likened the fossils to one of the incomplete specimens (S.A.M. 1066) described by Broom (1913a) as *P. capensis.* See below.

GREAT KARROO BASIN	White Band	Hantamsberg on farm Toren near Calvinia	Palaeoniscoid fish: *Palaeoniscus capensis*	3 incomplete specimens, none having a head. Impressions in shale. Broom (1913) said they were "probably Upper Dwyka". He did not mention the discoverer. Roger & du Toit (1909) listed *Elonichthys* sp. from the White Band near Calvinia. du Toit (1954) listed *P. capensis,* Broom from the White Band, with no mention of *Elonichthys.* We gather that du Toit (or Rogers) was the finder of the fossils near Calvinia, and that they derive from the White Band. (S.A.M. 1061, 1062, 1066).	Rogers & du Toit (1909, p. 193) "White Band . . . in Calvinia . . . *Elonichthys* sp." Broom (1913a) described and figured *P. capensis* from 12 miles west of Calvinia. No mention of *Elonichthys* sp. from Calvinia. du Toit (1954, p.279) "White Band–*Palaeoniscus capensis* Broom, Calvinia". No further mention of *Elonichthys.* Gardiner (1962, p.18): "*Elonichthys* sp., from the White Beds of the Upper Dwyka shales, * Clavinia" (*Typing error? Should read Calvinia"). We conclude that Broom (1913a) possibly renamed *Elonichthys* sp. from Calvinia as *Palaeoniscus capensis.* If correct, the latter is the valid name. Dr. R. A. Jubb (1972, written comm.), suggests that the three specimens of *P. capensis* described by Broom, probably represent more than one species.
		Langberg mountain, about 20 miles N.W. of Loeriesfontein	Palaeoniscoid fish	" . . . undoubted fin- and scale-impressions of Paleoniscus were seen."	Hälbich (1958, p.124).
	Dwyka? Ecca?	Kimberley, Diamond pipe	Palaeoniscoid fish: *Acrolepis addamsi*	5 fragmentary specimens on a single shaly sandstone block displaced within a Kimberlite pipe. Horizon, therefore, cannot be ascertained with confidence. Broom said it might be either Dwyka or Ecca. (We feel it could also be Beaufort.) (A.M.M.M.)	Broom (1913b) described and illustrated. Dr. R. A. Jubb (written comm., 1972): may involve 2 genera.
	Base of Upper Dwyka Shales	Blaauw Krantz**	Palaeoniscoid fish: *Namaichthys schroederi?* and others	Several specimens of dismembered fish in calcareous concretions. (A.M.M.M., collections 4902, 5008; B.P.I.P.R. P.11–P.23, P.29–P.42.)	Identified by Dr. R. A. Jubb from A.M.M.M. specimens. B.P.I.P.R. specimens recently collected by the authors.

* B.P.I.P.R. = Bernard Price Institute for Palaeontological Research, Johannesburg.
S.A.M. = South African Museum, Cape Town.
A.M.M.M. = Alexander McGregor Memorial Museum, Kimberley.

**Coprolites were found by the authors at Klipneus (B.P.I.P.R. I.42), Zwartbas (B.P.I.P.R. I.44) and Blaauw Krantz (B.P.I.P.R. I.18–I.37) (Figs 17–21). There are true coprolites as well as occasional heteropolar "spiral coprolites" that probably represent fossil spiral valves from the intestines of chondrichthyians (Williams, 1973, written comm.).

Heavy lines indicate new finds.

TABLE 5

LITERATURE ON THE MESOSAURIDAE FROM SOUTHERN AFRICA.

AUTHOR	IDENTIFICATION	SITE	MUSEUM NO.	FOSSIL DESCRIPTION	COMMENTS
Gervais (1865)	*Mesosaurus tenuidens*	Griqualand West, north of the Orange River (Kimberley area).	Museum of Natural History, Paris	Head, neck, forelimbs and most of thoracic and abdominal region.	Described only. No illustration. Found in about 1844 in Griqualand, north of the Orange River (i.e. in the Kimberley area). The specimen slab was being used by a Hottentot as a pot-lid!
Gürich (1889)	*Ditrichosaurus capensis*	Near Hopetown	?	Posterior region, with 1 slightly imperfect forelimb, ribs and vertebrae	Described and figured. "Remains are evidently those of an immature animal, and there seems little doubt that they are those of a young *Mesosaurus*" (Broom 1904 p.103).
Seeley (1892)	*Mesosaurus pleurogaster*	¼ ml. S. of Market Square, Kimberley.	British Museum (B.M.) 49972	Ribs and vertebrae.	Described.
	,,	100′ from E. margin of Kimberley mine.	B.M. 49971	Ribs and vertebrae.	Described.
	,,	40′ from E. margin of Kimberley mine.	B.M. 49973	Vertebrae and ribs. Seeley suggested it might be part of B.M. 49974.	Described and figured.
	,,	,,	B.M. 49974.	Vertebrae, ribs and hind foot.	Described.
	Mesosaurus tenuidens	Albania, Griqualand West.	S.A.M. ? 709	Head, forelimbs, torso. Ventral aspect.	Described and figured. Albania is a former farming area in the magisterial district of Herbert, between Hopetown and Douglas.
	Mesosaurus sp.	Near Burghersdorp.	Albany Museum, Grahamstown.	Dorsal aspect of vertebrae and ribs.	Brief description, no illustration. The town lies on Beaufort sediments close to the Stormberg contact, nearly 200 miles (320 km) from the nearest Dwyka outcrop. This record is suspect, as it is stratigraphically incompatible with other *Mesosaurus* records.
Broom (1904)	Probably *Mesosaurus tenuidens*	Discovered in Bushmanland by the Rev. Neethling of Nieuwoudtville	No mention.	Most of tail, hind limbs, abdominal and thoracic region and portion of skull.	Described and illustrated.
Broom (1908, p. 379)	1. *Mesosaurus tenuidens* Gervais	Near Calvinia.	S.A.M. ? 9327	Cervical region, ribs, left forelimb, poor skull cast.	Described and illustrated. "Species represented by the Paris type (Gervais 1895), this Calvinia specimen (Broom 1908), and possibly also the Nieuwoudville specimen (Broom 1904)".

	2. *Mesosaurus capensis* (Gürich)				On the S.A.M. specimen described by Seeley (1892): "The specimen . . . . must thus be regarded as a distinct species" (from *M. tenuidens*). Comparing Gürich's (1889) type specimen and the S.A.M. specimen described by Seeley (1892), Broom concluded that it is "highly probable that the Cape specimen is the adult of Gürich's type". "*M. capensis* represented by Gürich's type and the specimen described by Seeley from the S.A.M."
	3. *Mesosaurus pleurogaster* Seeley				"Very imperfectly known".
Broom (1913c, p. 358–360)	*Noteosaurus africanus*	Victoria West district	S.A.M. 2355	Pelvic region with the anterior part of the tail and the greater part of the two hind limbs.	Described and illustrated. "the possession of 6 phalanges in the 5th toe of *Noteosaurus* is a striking difference from *Mesosaurus* when certainly there are only 4 in the known specimens". With regard to its geological setting: "There is no doubt it is from the same horizon as the South African species of *Mesosaurus*". Haughton (1920, p. 9), however, noted that in no portion of the Victoria West district has the White Band been mapped, although it occurs just outside the boundary to the N. of Vosburg. He concluded that "It is just possible, therefore, that *Noteosaurus* is from the Lower Ecca shales". We regard the location of Broom's *Noteosaurus* as effectively unknown.
Reuning & von Huene (1925)	*Mesosaurus tenuidens*	Doros, in the Kaokoveld. 20° 45′ S. 14° 15′ E.	?	Fractured, disarticulated ribs, vertebrae and some extremity bones. No skulls.	Originally described as occurring in a volcanic breccia underlain by tuffaceous beds containing volcanic "Kalkbomben". Martin (1961, p.40) re-examined the site and described the fossil bed as being a dark course, conglomeratic quartzite band about 1 foot thick containing numerous rolled and broken *Mesosaurus* bones. The erroneously described "Kalkbomben" of Reuning are apparently calcareous concretions. Coaly carbonaceous shales occur about 300 ft (90 m) below the *Mesosaurus* zone and seem to be equivalent to the Auob sandstone coals.
von Huene (1925)	*Mesosaurus tenuidens*	He reviewed the literature without re-examination of the South African material, and suggested that all the previously described South African *Mesosaurus* species might be included under *M. tenuidens*. He made no mention of *Noteosaurus africanus*. In discussing the dispersed bones in the Doros bonebed in the Kaokoveld (north of the Windhoek highlands), he concluded that, because of the lack of distinguishing features, they belong to the same species as occurs in the Kalahari and Karroo basins, namely *M. tenuidens*.			
von Huene (1941, p.55)		With regard to *Noteosaurus*: "I suspect that the data given on *Mesosaurus* (including *Stereosternum* etc.) of 4 phalanges in the 5th toe is based only on incomplete preservation. If this is so, the genus name *Noteosaurus* has to disappear".			

continued overleaf

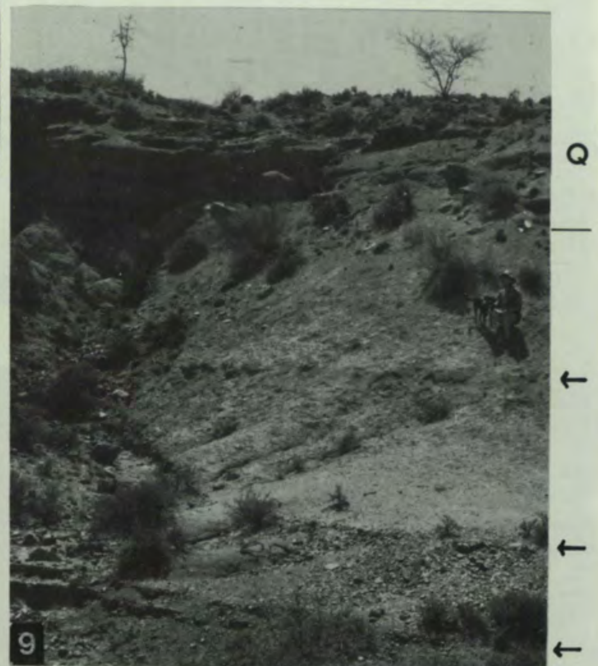
TABLE 5–*Continued*

AUTHOR	IDENTIFICATION	SITE	MUSEUM NO.	FOSSIL DESCRIPTION	COMMENTS
Haughton & Frommurze (1927, p. 14)	*Mesosaurus* sp.	Kanibeam, Warmbad basin.	No mention	"A few moulds of bones"	Only mentioned.
Haughton & Brink (1954)	*M. tenuidens* (Gervais) *M. pleurogaster* (Seeley) *M. capensis* (Gürich) Broom *Noteosaurus africanus*				Bibliographic list only. von Huene (1925, 1941) was not mentioned.
Stromer (1914)	*Mesosaurus* sp.	Kabus (Khabus 146), farm N. of Keetmanshoop, S.W.A.	?	A hind limb and a hand.	Described and illustrated.
Martin (1953, Pl. V, p. 39)	*Mesosaurus* sp.	Gellap-Ost 3 and Khabus 146, farms N. of Keetmanshoop, S.W.A.	Windhoek Museum?	?	Localities shown on map. The *Mesosaurus* remains are from a "fine, hard siltstone . . . . The White Band, which can still be recognised in the Warmbad district, is not developed here". von Huene (1925) referred to the Khabus specimen as *M. tenuidens.*
Martin (1961, p. 14).	*Mesosaurus* sp.	Gross Daberas, 17 miles N.E. of Tses, S.W.A.	Windhoek Museum	P.C. 37*: lower part of body and portion of tail. Poorly preserved.	Only mentioned. *Heath (1966, Pl. XXII) illustrated specimen P.C. 37.

There are undescribed specimens in various museum collections (their localities are indicated on fig. 1):

1. In S.A.M. (South African Museum, Cape Town) there are about ten specimens (without skulls) from sites in the Western Cape: Laingsburg gypsum works; Tankwa Karroo, N.W. of Laingsburg; Toren, 12 miles (19 km) W. of Calvinia; Ezels Fontein farm, N.W. of Loeriesfontein; Brandvlei, 120 km E.N.E. of Loeriesfontein.
2. Mr. B. Oelofsen of Stellenbosch University Zoology Department is presently making a collection from the Loeriesfontein district.
3. The A.M.M.M. (Alexander McGregor Memorial Museum, Kimberley) has rib, vertebrae and limb moulds, mostly from the Kimberley townlands, but there are also specimens catalogued from farther afield at Belmont, Heuningneskloof and Kameelpan (32 km N.E. of Kimberley).
4. The State Museum in Windhoek, S.W.A. apparently has a number of specimens. We have confirmation of one from near Haib (Mr. C. G. Coetzee, Director, written comm. to Dr. E. P. Plumstead, B.P.I.P.R.),? three (with skulls) from Kirchberg farm, N.W. of Warmbad, and ? one from Commissioner's Pan, N.E. of Loeriesfontein (Dr. A. Keyser, Geological Survey, Pretoria, pers. comm.).

It would seem that the Mesosauridae are in need of revision before meaningful comparisons can be made between the African and South American species, where *M. braziliensis* and *Stereosternum tumidum* occur.



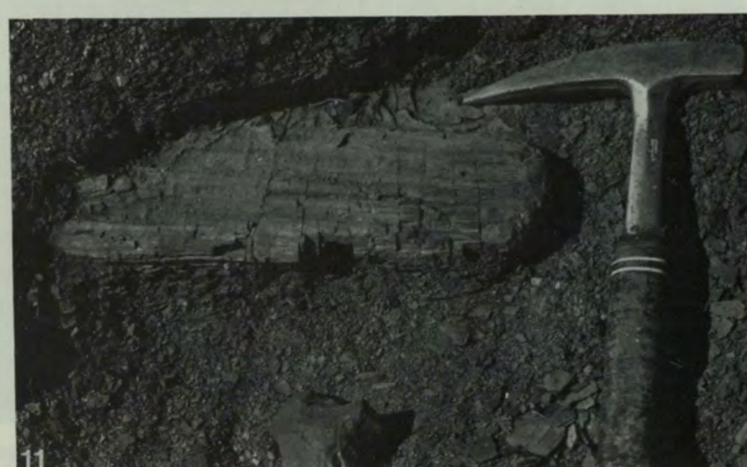
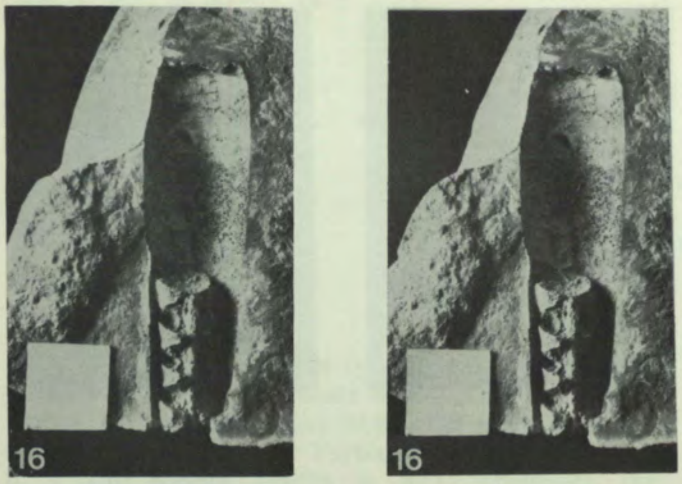
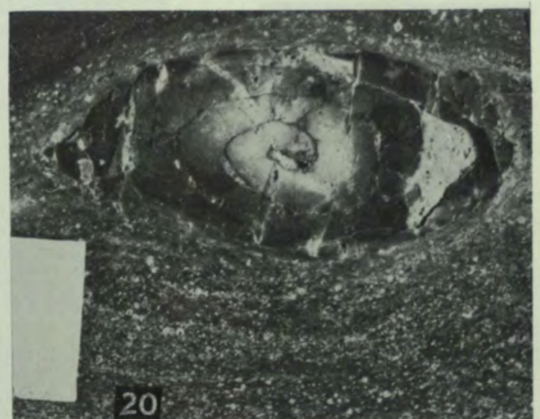
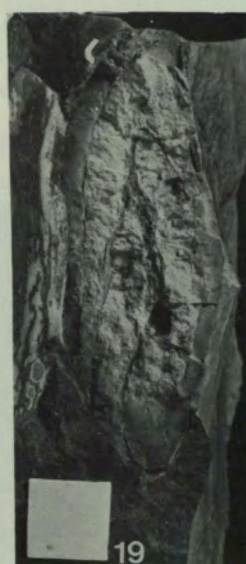


Fig. 6: Blaauw Krantz Site viewed from the east, showing stratigraphy.
Fig. 7: Varved shale at Blaauw Krantz. Dropstones to the right and left of hammer head, arrowed.
Fig. 8: Concretion in situ at Blaauw Krantz.
Fig. 9: Fossiliferous zone at Blaauw Krantz. "Q" indicates Quaternary sediments. The arrows indicate fossiliferous concretion horizons.
Fig. 10: Fossil wood from Blaauw Krantz (Specimen BK3). Transverse section (x½).
Fig. 11: In situ fossil wood at Olie Rivier. Note rounded end.

Orthocerid cephalopods—Blaauw Krantz
Figs. 12—14: Internal moulds of body chamber (x1).
Fig. 12—Lateral view I.3 (Stereopair x1).
Fig. 13—Dorsal view I.3 (x1).
Fig. 14—Ventral view I.3 (Stereopair x1).
Fig. 15: External mould, showing ornamentation I.4 (x2).







Blaauw Krantz fauna

Fig. 16: Orthocerid cephalopod. External cast and partly preserved septa and siphuncle, I.9 (Stereopair x1).

Fig. 17: Coprolite, consisting partly of fish scales P.44 (x½).

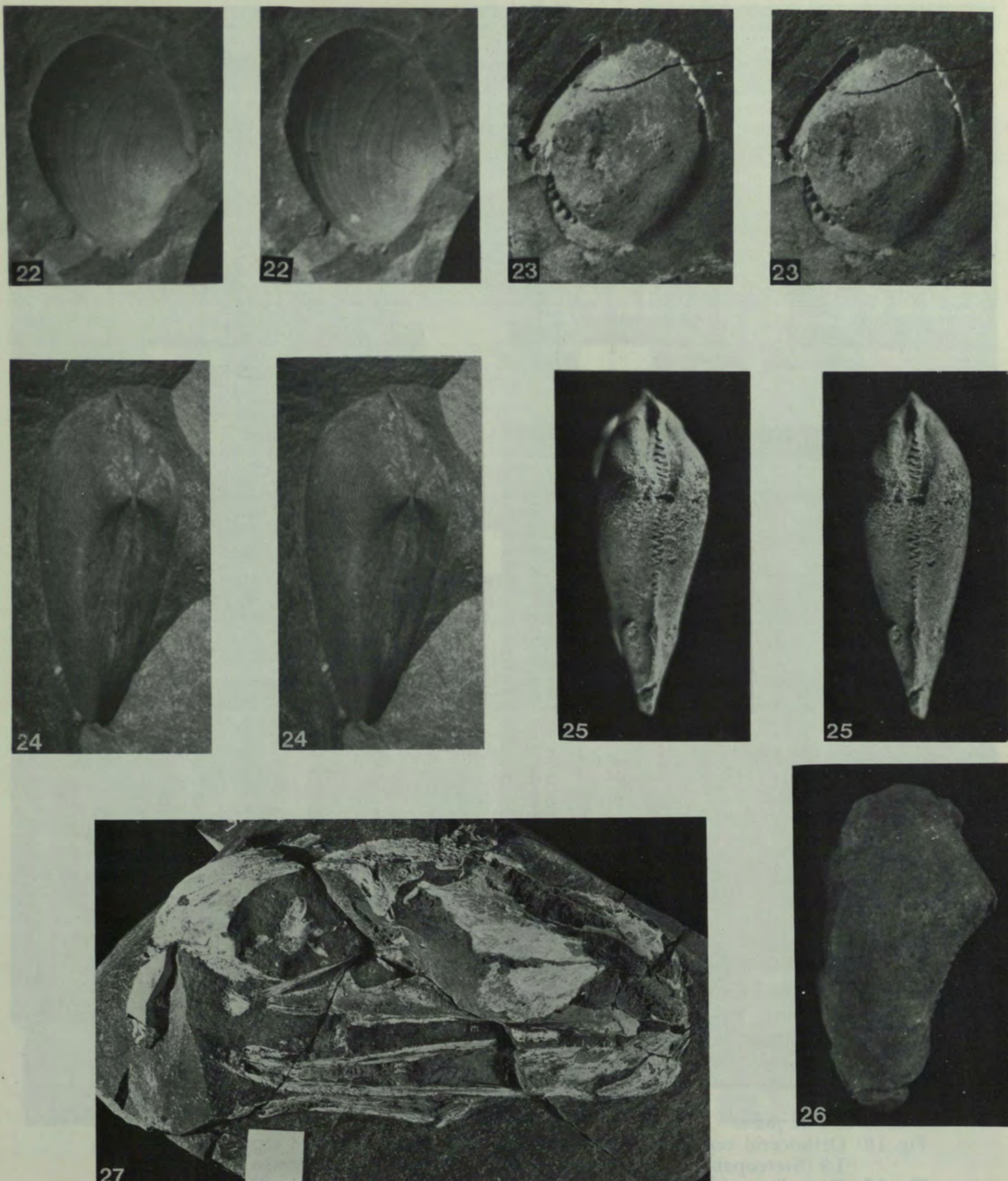
Figs. 18–21: "Spiral coprolites"

Fig. 18–Longitudinal section of heteropolar spiral coprolite ("enterospira" of Williams, 1972) I.20 (Stereopair x1).

Fig. 19–Longitudinal section showing more coarsely coiled structure I.24 (x1).

Fig. 20–Transverse section of coprolite with finely coiled structure I.18 (x2).

Fig. 21–Transverse section of more coarsely coiled coprolite I.26 (x2).



Blaauw Krantz fauna

Figs. 22–26: Lamellibranchs (x5).

Fig. 22–*Nuculopsis* sp. External mould. Lateral view, I.39 (Stereopair).

Fig. 23–*Nuculopsis* sp. Internal mould. Lateral view, I.39 (Stereopair).

Fig. 24–*Phestia* sp. External mould. Dorsal surface I.38 (Stereopair).

Fig. 25–*Phestia* sp. Internal mould. Dorsal view I.38 (Stereopair).

Fig. 26–*Phestia* sp. Internal mould. Lateral view I.38.

Fig. 27: Palaeoniscoid fish skull in concretion. Lateral view P.15 (x1).

Palaeont. afr., **15**, 65–67. 1973

THE MODE OF LIFE OF GORGONOPSIANS

by

A. R. I. Cruickshank

The gorgonopsians as typically developed were undoubtedly the dominant land carnivores of the Upper Permian and have been compared with the sabre-tooth cats of the Tertiary (Parrington, 1955, p. 7 and Kemp, 1969b, p. 321). However, the similarities between the two groups are almost entirely confined to their dentitions and the general proportions of their lower jaws, both possessing greatly enlarged canine teeth and relatively weak coronoid processes on the lower jaw. In addition, both groups show adaptations to allow the lower jaw to make a wide gape, thus allowing the upper and lower canines to clear each other when the jaw is opened and, at the same time, keeping the jaw articulations from dislocating during this movement.

The popular image of a Tertiary sabre-tooth is of a powerful animal leaping on to the back of a medium-sized ungulate and stabbing the canines into the back of the neck, or some other similar vital spot (e.g. Augusta and Burian, 1960, plate 58). By analogy a similar method of attack is assumed for the typical gorgonopsians (e.g. Crompton, 1968, fig. 12).However, Bohlin (1940; 1947) has discussed the method of feeding of one of the more typical Tertiary sabre-tooths (*Smilodon*) and has concluded that the forms with the exaggeratedly elongated canines would make very poor active predators, tending to break their canines in a leap on to their prey, and in any case being unsighted while leaping with their mouths open and their canine teeth poised for killing. Bohlin suggests alternatively that these forms with the long canines were in fact better suited to a scavenging way of life and were able to use their long canines on the relatively thick-skinned larger pachyderms of the time. The canines seem adapted to pierce the skin of the belly and so enable the cat to cut up and eat the softer portions of the carcase. However, it is obvious that if they were scavengers their teeth were not adapted to crush bone as do the hyaenas.

An extension of this idea springs from the recent redescriptions by the van Lawick-Goodalls (1971) of hyaenas hunting actively and killing prey by a concerted pack effort, involving the disabling of the running prey by an attack on the hamstring muscles, or the belly. Thus, the sabre-tooth cats, with much the same physical build of a hyaena, could have disabled their prey by similar methods. It is assumed that as the hyaenas prey on small and medium-sized ungulates, the sabre-tooths could possibly have attacked the heavier pachyderms in a similar way.

Bohlin (pers. comm.) has observed the mode of feeding of the large Komodo Dragon (*Varanus komodoensis*) which may have some relevance to this line of thought. He described how a tethered goat was attacked in the wild by one of these big lizards and dispatched remarkably quickly.

The first move was a slashing attack with the teeth on the soft under belly of the prey, followed by the prey being gripped and shaken energetically and thus eviscerated. While the goat was expiring the viscera were eaten, followed by the carcase starting at the head. The whole process took only a few minutes and left little but a damp patch on the ground.

Thus, if gorgonopsians had a mode of life in between that of a hyaena and that proposed for the Tertiary sabre-tooth cats by Bohlin, the enlarged canines would be suitable to pierce the skin of their prey and thus a similar mode of dispatch of the prey used by the Komodo Dragon could be postulated for the gorgonopsian.

However, while all the foregoing have been based on an assumption that it is the typical large gorgonopsians that were involved, it must be remembered that the Gorgonopsia are divided into two families viz. the Gorgonopsidae and the smaller Ictidorhinidae (Sigogneau, 1970a and b). Kemp (1969b, pp. 54–63) has described in detail the olfactory structures to be expected in the former group and it is obvious from his arguments and the relatively small size of the orbit in these animals that they were primarily "olfactory hunters". On the other hand the Ictidorhinidae have relatively much larger orbits, are generally smaller animals and seem to be more scarce in the fossil record. Keyser (1970, p. 688) pictures the Upper Permian Karroo environment "... as a dry playa or pan-like flat, almost devoid of vegetation, traversed by water courses along which both vegetation and animal life was concentrated". This vegetation he thinks (op. cit., p. 687) was mainly equisetalian. Furthermore, Kemp (1969a, p. 231) notes "... it seems certain that they (the gorgonopsians) must have had a high degree of mobility of their heads, including the ability to rotate their skulls about a longitudinal axis ... to use their jaws laterally". That oblique blows of the

* Originally presented to Section D of the South African Association for the Advancement of Science, Johannesburg–July 1972.

head and thus the canines could be delivered is indicated by the relatively large insertion areas for the dorsal and lateral neck muscles, as compared with those for head depressors (Sigogneau, 1970a, figures many gorgonopsian occiputs illustrating this feature).

The pose of the body would from this assumption be different from that which Colbert (1949) or Romer (1966, p. 179) suggest, with the "... hind limbs (tending) to be underneath the body, making support easier". A sprawled or semi-sprawled typically reptilian gait would necessitate strong lateral movements of the head, particularly if the canines were to be used to disembowel the prey.

Finally, a gorgonopsian (in exactly the same way as a sabre-tooth cat) launching itself at its prey would more than likely break its canines the first time it did so (Bohlin, 1940, fig. 1 and 2; 1947, fig. 1). That they could not have acted so is reflected in their success in the upper Permian.

The interpretation put on all the foregoing speculation is that the larger Gorgonopsidae lived on the larger bulky and probably sluggish anomodonts (Keyser, 1970, p. 688), hunting their quarry by scent through the vegetation along the river banks, attacking their soft under belly with their powerful canines and thus disembowelling them before ripping the flesh off the carcase with their powerful incisors and bolting it wholesale.

The smaller, more keen-sighted Ictidorhinidae possibly lived in the open areas and hunted the small, active lizard-like animals *Millerosarus* and *Milleropsis* that Gow (1962, p. 261) has redescribed.

The larger Gorgonopsidae seem to have been replaced to a certain extent by the whaitsiid Therocephalia in the uppermost Permian *Daptocephalus* zone (Kitching, 1970) where this zone fossil is seen to replace the earlier large anomodonts such as *Aulacephalodon* and *Rachiocephalus* (Keyser, 1970, p. 688). Thus, the concept of these large Therocephalia being purely scavengers as hitherto thought by many also deserves reconsideration.

A final thought concerns the dentition of the Gorgonopsidae and Whaitsiidae. The former have a highly reduced post-canine dentition, and the latter have none and this has caused some discussion in various places in the past. However, if it is realised that one important difference between a reptile and a mammal is the ability of the latter to alternate the shearing pressure from one cheek to the other while feeding and that in carnivores this is an important mechanism particularly in bone-crushing, then a plausible solution to this enigma becomes possible.

The Gorgonopsidae had a highly developed jaw hinge which would seem to preclude any possibility of such an alternation of shearing pressure (Parrington, 1955). Likewise, Kemp (1969b) has described in detail the mechanism used by these animals to mesh the upper and lower incisors, apparently to aid them in pulling flesh off their prey. However, if the flesh was bolted, no mastication would be necessary and finally it must be remembered that the bones of the synapsids had not developed marrow at that time and so no necessity would exist for a mechanism to extract their marrow. This last factor also would therefore be important in the whaitsiid Therocephalia, and might also explain why they had no post-canine teeth at all.

I am grateful to several people for discussing and criticising the ideas expressed above, more particularly I am indebted to Mr. J. W. Kitching, Dr. A. W. Keyser, Mr. C. E. Gow and Dr. T. S. Kemp. Nonetheless, the opinions are almost entirely my own.

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Printed by The Natal Witness (Pty) Ltd., Pietermaritzburg, Natal.