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KAROO SUPERGROUP PALAEONTOLOGY OF NAMIBIA AND BRIEF DESCRIPTION OF A THECODONT FROM OMINGONDE

by

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ABSTRACT

Karoo strata crop out extensively in Namibia. Numerous and diverse fossils have been collected from three areas – Karasberg, Kalahari and Huab Karoo basins. Although a great deal of research has been done on these strata and their fossil content, the literature is scattered and no publication has been devoted to a detailed review of what has been achieved. This paper presents a review based principally on a literature search allied to personal experience of some of the fossils and field trips to a few localities. It cannot pretend to be an in-depth review. The Namibian Karoo outcrops are so extensive and the palaeontological remains so diverse, that several years of intensive research would be required to achieve such a work. Tragically, many of the fossils mentioned in the text have been lost or their whereabouts are unknown. A small sample of fossils is housed in the Geological Survey Museum, Windhoek, and other fossils are known to be curated by the South African Museum, Cape Town, the Bernard Price Institute for Palaeontological Research, Witwatersrand University and the Geological Survey of South Africa, Pretoria. A thecodont from the Omingonde Formation (Upper Triassic) is described briefly.

INTRODUCTION

Extensive outcrops of late Palaeozoic and Mesozoic sediments occur in southern and northwestern Namibia (Smith *et al.* 1993) (Figure. 1-2). These strata accumulated in intra-cratonic settings, and have not suffered greatly from folding since their deposition. Traditionally these sedimentary rocks have been assigned to the Karoo Supergroup, which is widespread in southern Africa, with important equivalents in South America. (Figure 1).

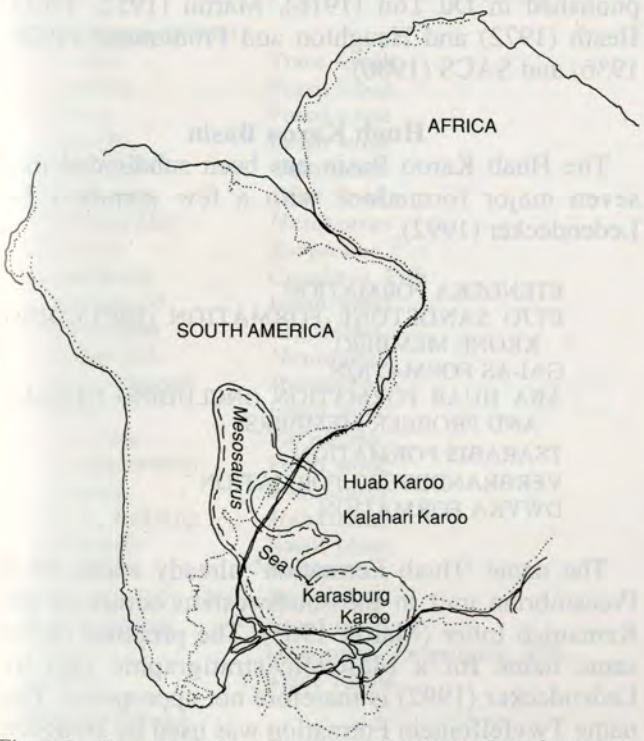

Figure1. Reconstruction of southern Gondwana based on maps by Owen (1983), showing the probable extent of the *Mesosaurus* sea. Note that in this reconstruction the sea does not have the 'central arm' separating Namibia from Brazil (Oelofsen, 1987). *Mesosaurus* sea may have been landlocked, or could have had a limited connection with other oceans of the period.

PALAEOGEOGRAPHY

There has been some debate about the palaeogeography of the Karoo Basins, especially during Whitehill times, recently summarised by Remelin (1994) and Smith *et al* (1993). Most reconstructions, such as the one by Oelofsen (1987) contain a "central sea arm" between South Africa and South America which leads into the ocean that surrounded Gondwana, meaning that the "*Mesosaurus* Sea" would have had direct connections with the ocean. However, sedimentary, volcanological and palaeontological considerations suggest that there was no such "central sea arm" and that there was little likelihood of a major connection to the ocean. Instead the "*Mesosaurus* Sea" appears to have been an isolated, relatively shallow inland sea. Examination of various palaeogeographic reconstructions of southern Gondwana suggests that the "central sea arm" may be an artefact arising from the method of palaeogeographic reconstruction. Reconstructions of Owen (1983), in which the Triassic globe is considered to have had a radius 20% smaller that the modern radius, result in the disappearance of the "central sea arm" and produce a land locked "*Mesosaurus* Sea" (Figure 1). Owen's reconstruction accords better with the geological and palaeontological evidence than do those in which a 500 km wide ocean gap – the central sea arm – existed between Africa and South America.

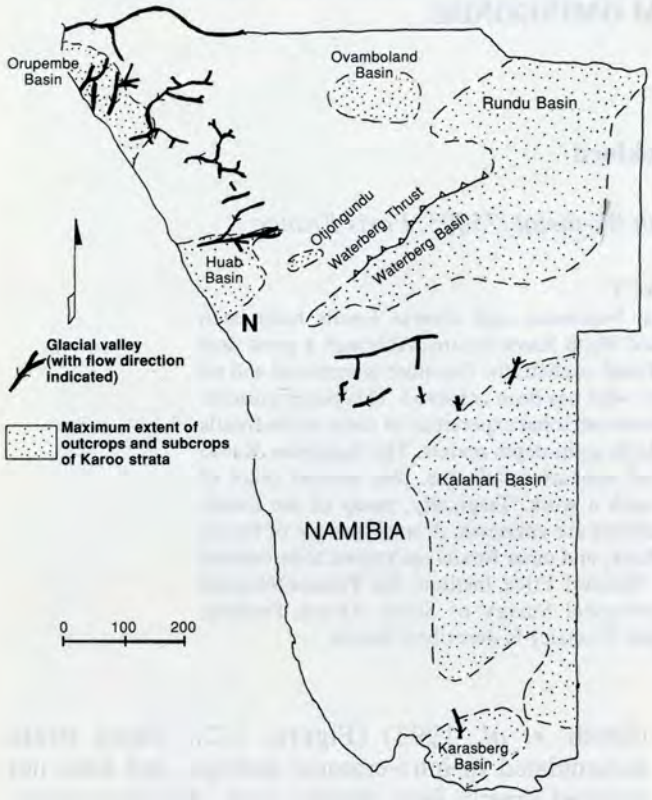

Figure 2. Karoo Basins of Namibia. Karoo outcops and subcrops occur widely in Namibia, the various basins being separated from one another by areas of non-deposition and of erosion. Numerous glacial valleys of Dwyka age occur in the northwest, centre and south of the country. The Waterberg thrust has resulted in Late Proterozoic dolomites being overthrust southwards over Mesozoic strata for distances of at least 4 km.

STRATIGRAPHY

The South African Karoo spans a considerable period of time. The Dwyka is considered to span the Late Carboniferous (Westphalian) to Early Permian (Artinskian) (Visser 1990; Visser *et al.* 1990). The Ecca extends into the early part of the Late Permian (Kazanian) (Rubidge 1991). The youngest rocks admitted to the Karoo are the Etendeka lavas which are early Cretaceous (Erlank *et al.* 1994). The Karoo Supergroup as a whole thus spans the period ca 320 Ma to ca 120 Ma.

Four of the five main stratigraphic groups which comprise the Karoo of South Africa are recognised in Namibia: Dwyka, Ecca, "Stormberg" and Drakensberg Groups. According to Smith *et al.* (1993) the Beaufort Group appears not to be represented in Namibia. However, strata which may be partly equivalent in age to the Beaufort Group of South Africa occur at Omingonde, but these sediments are correlated with the Stormberg by Smith *et al.* (1993).

The Etjo (Plateau) Sandstones are possibly equivalent in age to the Clarens Formation of South Africa (Smith *et al* 1993) although some of them are appreciably younger. In the Etendeka region north of the Huab Basin, lavas of early Cretaceous age overlie aeolianites which may have been active dunes until buried by the lavas. Some of the barchan dunes are intercalated between lava flows and are thus clearly Cretaceous in age (Horsthemke *et al.* 1990; Erlank *et al.* 1984). The fact that several of the Etendeka volcanic units also outcrop in Brazil indicates that break-up of South America and Africa in the latitude of Namibia was achieved later than the Early Cretaceous, (Milner *et al.* 1995; O'Connor & Le Roux 1992).

The extensive outcrops of basalts and intercalated sedimentary rocks in the Mariental region have been mapped as Jurassic. They have not been studied extensively, but could be rewarding from a palaeontological viewpoint as the sediments are of continental affinities. The recent discovery of conchostracans in the Hardap Resort area by R. Swart is of interest in this respect.

Karasburg and Kalahari Karoo Basins

In the south of Namibia, the Karasburg and Kalahari Basin Karoo rocks have been subdivided into four main formations (Oelofsen 1981).

AUSSENKJER FORMATION
WHITEHILL FORMATION
PRINCE ALBERT FORMATION
DWYKA FORMATION

The succession from the Prince Albert Formation to the Aussenkjer Formation is correlated with the Ecca Group. Detailed stratigraphic successions were published in Du Toit (1916), Martin (1952, 1961), Heath (1972) and Haughton and Frommurze (1928, 1936) and SACS (1980).

Huab Karoo Basin

The Huab Karoo Basin has been subdivided into seven major formations with a few members by Ledendecker (1992).

ETENDEKA FORMATION
ETJO SANDSTONE FORMATION (INCLUDING KRONE MEMBER)
GAI-AS FORMATION
ABA HUAB FORMATION (INCLUDING GUDAUS AND PROBEER MEMBERS)
TSARABIS FORMATION
VERBRANDEBERG FORMATION
DWYKA FORMATION

The name 'Huab Formation' already exists for a Precambrian unit in the southwestern corner of the Kamanjab Inlier (Martin 1965). The proposal of the same name for a Mesozoic stratigraphic unit by Ledendecker (1992) is therefore not appropriate. The name Twyfelfontein Formation was used by Hodgson and Botha (1978) for the entire suite of strata between the Dwyka Tillite and the Etjo Sandstone in the Huab region, and is thus not available for a subdivision of the unit. The replacement name Aba Huab Formation proposed here would be an appropriate name for the Huab Formation of Ledendecker (1992).

TABLE 1.
List of Karoo Supergroup Fossil Localities in Namibia.

Ovambo District	
Strata Test N°1	Permian Miospores
Damaraland District	
Doros Crater	*Mesosaurus*
Doros to Gai-as	*Mesosaurus*
Probeer 535	Fossil wood
Krone 721	Fossil wood
Rhino Wash	Trace fossils
Rooiberg 517	Fossil wood
Twyfelfontein 534	Fossil wood
Verbrander Berg	Fossil wood, *Glossopteris*
Vrede 719	Fossil wood, *Paracalamites*
Otjiwarongo District	
Omingonde	cf *Erythrosuchus*
Otjihaenamaperero	Tetrapod tracks
Waterberg Plateau	Tetrapod tracks
Grootfontein District	
Breitenbach 152	Reptilian skull
Neudorf	Tetrapod tracks
Reheboth District	
Schlip	Radiolaria
Vingerbreek Oos 473	Goniatite
Mariental District	
Amalia	*Megaporoxylon zellei*
Goamus	Fossil wood
Hardap Resort	Conchostracans
Hardap 110	*Eurydesma*, Brachiopod, Starfish
Kameelhaar	Stromatolites
Mariental	Starfish, Bryozoa, Gastropoda
Norronaub	Spores
Vipersdorf	*Peruvispira vipersdorfensis*
Keetmanshoop Distirct	
Ai-Ais	Trace fossils
Areititis	Fossil wood
Aurus	Fossil wood
Berseba	Fossil wood
Brukkaros	Gastropods
Chamaites	Trace fossils
Daberas Ost	*Mesosaurus*
Daweb	*Eurydesma*
Ganikobis	*Conularia*, Fish
Garinais 30	Fossil wood
Gavetaams	*Eurydesma*
Gellap Ost	*Mesosaursu*
Gross Daberas	*Mesosaurus*
Huns	Fossil wood
Itsawisis	*Eurydesma*
Keetmanshoop	Fossil wood
Khabus	*Mesosaurus*
Klein Spitzkop	*Mesosaurus*
Mukorob	Fossil plants
Nabaos	*Eurydesma*
Nanebis Berg 120	*Mesosaurus*
Schlangkopf	Fossil wood
Tses	*Orthoceras, Peruvispira*, Fish
Zaris	Trace fossils
Karasberg District	
Aussenkjer 147	Fossil wood
Gooie Hoop	Limulid trace fossil
Haib	*Aphanaia haibensis, Mesosaurus*
Kanabeam	Foraminifera
Kirchberg 13	*Phyllotheca*, arthropods, *Mesosaurus*
Vioolsdrift	Trace fossils
Zwartbas	Trace fossils

The succession from the Verbrandeberg Formation to the Gai-As Formation is included by Ledendecker (1992) in the Ecca Group, while the Etjo Sandstone has been correlated with the Stormberg Group.

The sedimentary succession cropping out at Omingonde spans a period which is not well represented elsewhere in Namibia. It consist of two main formations (Keyser 1973a, b):

ETJO (PLATEAU) SANDSTONE FORMATION
OMINGONDE FORMATION.

The Omingonde Formation was correlated with the *Cynognathus* zone of the Beaufort Group by Keyser (1973 a, b) while the Etjo Sandstone has traditionally been correlated with the Stormberg Group. It is unsure, however, whether the Etjo Sandstone in the type area is really the same unit as the 'Etjo' Sandstones at the base of, and interbedded with the Etendeka Lavas, and furthermore whether it is indeed the time equivalent of the Stormberg Group of South Africa.

Jurassic lavas near Hardap

Extensive outcrops of Jurassic lavas occur in Mariental District. Intercalated between lava flows are sediments of various sorts, in particular evaporites. Few fossils have been found in these strata, perhaps reflecting a lack of prospecting because they are known to yield fossils at Hardap.

PALAEONTOLOGY

The Namibian Karoo Sequence rocks are richly fossiliferous, and have yielded both microscopic and macroscopic fossils at many localities (Table 1). These range from miospores and algae to vascular plants, invertebrates, fish and reptiles.

Karoo fossils provided the first palaeontological evidence to be cited in support of Wegener's theory of continental displacement (Figure. 1). The fossil marine reptile *Mesosaurus* has a restricted distribution in southwestern Africa and Brazil, which indicated to Du Toit (1927) that the two areas had once been much closer together than they are now. Further studies have amply confirmed the overall similarity in depositional successions and fossil content in Brazil and Namibia during Karoo times (Oelofsen & Araujo 1987).

It is convenient to examine the Namibian Karoo fossils in stratigraphic order : Dwyka – Ecca – Omingonde – Etjo – Hardap. Dingle *et al.* (1983) and Anderson & Anderson (1985) considered the Dwyka to be Permian, whereas Oelofsen (1981), regards the Dwyka as late Carboniferous to Early Permian, and the Ecca to be early Late Permian. The Omingonde Formation was considered by Keyser (1973) to be Triassic and the Etjo Sandstones which overlie the Omingonde Formation were reported to be late Triassic to Jurassic. Direct evidence of the age of the Etjo Formation is lacking. However, indurated sand dunes intercalated in the base of the Etendeka Lavas must be of early Cretaceous age (Erlank *et al.* 1984).

TABLE 2
List of organisms and their traces from the Dwyka Group of Namibia (* = holotype from Namibia)

Sporites Potonié, 1983
Triletes Reinsch, 1881
Azonotriletes Luber, 1935
Laevigati Bennie & Kidston, 1886
Punctatisporites foveolatus Maheshwari & Bose, 1969
*Leiotriletes etoshae** Stapleton, 1977
Leiotriletes sup. Naumova, 1937
Retusotriletes diversiformis (Balme & Henneley, 1956)
Apiculati Bennie & Kidston, 1886
Cyclogranisporites sp. Potonié & Kremp, 1954
*Converrucosisporites ovambolandensis** Stapleton, 1977
Verrucosisporites trisectus Balme & Henneley, 1956
Apiculatisporis spiniger (Leschik, 1959)
Anapiculatisporites ericianus (Balme & Henneley, 1956)
*Anapiculatisporites vuureni** Stapleton, 1977
Raistrickia sp. Schopf, Wilson & Bentall, 1944
Horriditriletes concavus Maheshwari, 1969
Horriditriletes novus Tiwari, 1965
Horriditriletes ramosus (Balme & Henneley, 1956)
Convolutispira sp. Hofmeister, Staplin & Malloy, 1955
Zonales Bennie & Kidston, 1886
Zonotriletes Waltz, 1935
Cingulati Potonié & Kaus, 1954
Densosporites sp. Berry, 1937
Cristatisporites mammilatus Maheshwari, 1969
Zonati Potonié & Kremp, 1937
*Kraeuselisporites maior** Stapleton, 1977
Kraeuselisporites minor Stapleton, 1977
Cirratriradites australensis Hart, 1963
Pollenites Potonié, 1931
Saccites Erdtman, 1947
Monosaccites Chitaley, 1951
Cordaitina obscura (Lele, 1964)
Potonieisporites novicus Bhardwaj, 1954
Nuskoisporites rotatus Balme & Henneley, 1956
Striomonosaccites ovatus Bhardwaj, 1962
Disaccites Cookson, 1947
Striatiti Pant, 1954
Protohaploxypinus cf *diagonalis* Balme, 1970
Protohaploxypinus goraiensis (Potonié & Lele, 1961)
Protohaplodypinus sp. Samoilovich, 1953
Hamiapollenites perisporites (Jizba)
Vittatina costabilis (Wilson)
Vittatina ovalis Klaus, 1963
Vittatina saccifer Jansonius, 1962
Vittatina subsaccata Samoilovich, 1953
Vittatina sp. Luber, 1939
Disaccitriletes Leschik, 1955
Illinites pemphicus Klaus, 1963
Disaccimonoletes Klaus, 1963
*Limitisporites rotundus** Stapleton, 1977
Plicates Naumova, 1937
Monocolpates Wodehouse, 1935
Intorti Naumova, 1937
Cycadopites follicularis Wilson & Webster, 1946
Cycadopites nevesi (Hart)
Striaticolpates Bose & Kar, 1966
Monostriocolpites Bose & Kar, 1966
Fusacolpites fusus Bose & Kar, 1966
Sporites Incertae sedis
Schizoporis gondwanensis Hart 1963
Radiolaria
Vascular plants
Foraminifera
Hyperammina
Ammodiscus
Glomospira
Ammobaculites
Spiroplectammina
Trace Fossils
Isopodichnus
Diplichnites Dawson, 1873
Umfolozia sinuousa Savage, 1971
*Punctichnium namibiensis** Ledendecker, 1992
Gluckstadtella cooperi Savage, 1971
Annelida (Scolecodonts)
Conulariida
Conularia
Mollusca
Eurydesma mytiloides Reed, 1932
Eoasianites (Glaphyrites) sp. Ruzhencev, 1936
Orthoceras sp.
*Peruvispira vipersdorfensis** Dickins, 1961
Conchostraca
Bryozoa
Dyscritella cf D.sprinigera (Bassler, 1929)
Porifera
Asteroidea
cf Monasteridae Schuchert, 1915
Crinoidea
Echinoidea
cf *Archaeocidaris* sp.
Pisces
*Namaichthys** *schroederi** Gürich, 1923
*Watsonichthys lotzi** (Gürich, 1923)
Elonichthys? sp.
Rhadinichthys? sp.
Fish Genus V

Dwyka Group

In Namibia Dwyka sediments consist predominantly of diamictites of glacial origin, interbedded with shales, often occurring in glacially sculpted valleys (Martin 1953, 1961). For this reason much of the strata tend to be poorly fossiliferous. However, in southern Namibia fossils have been found in various localities, the bulk of them in Rehoboth, Mariental, Keetmanshoop and Karasberg Districts.

In northern Namibia, there are good exposures of Karoo Supergroup strata in the Huab area. The two basal units have been correlated to the Dwyka (Horsthemke *et al.* 1990). No body fossils have yet been found there, but trace fossils, probably made by arthropods, are known.

Miospores

Stapleton (1977) described miospores from a borehole known as the Strat Test N° 1, which was drilled in the Ovambo Plain immediately north of Etosha Pan. Shales assigned to the Dwyka were encountered between 312 and 527 metres depth. The microfossils were obtained from depths of 368, 377, 436 and 519 metres. These shales overlie 41 metres of diamictite, and thus might belong to the Ecca Group. Additional information is provided by Roveda (1964), summarised in Hedberg (1979). Thirty-nine species of miospores were recorded from this borehole (Table 2), of which six were new to science. The assemblage as a whole indicated to Stapleton (1977) that the shales were of Early Permian age. A Sakmarian correlation

(ca 270 Ma) would satisfy the evidence. Leschik (1959) described a miospore assemblage from the southern part of Namibia, but there were apparently problems of preservation which render many of his determinations suspect (Hart 1963).

Roveda (1964) described three miospore associations from depths of 348, 401, and 483 metres in the Strat. Test N° 1 borehole. At a depth of 348 metres the assemblage is considered to be late Palaeozoic, probably Early Permian (Hedberg 1979). At 483 metres an assemblage similar to that from the Karoo of the Orange Free State is probably of Late Carboniferous age (Roveda 1964).

Vascular plants

Pieces of fossil wood have been reported from the Dwyka Group in Namibia (Martin & Wilczewski 1970; Haughton & Frommurze 1928; Heath 1972), but this needs confirmation as Oelofsen (1981) reports that he could not find any such material *in situ*.

Radiolaria

Martin & Wilczewski (1970) reported the prescence of Radiolaria in the so-called *Eurydesma* beds (glacio-marine Dwyka Beds) at Schlip and Ganikobis, but no details are available on the genera and species present.

Foraminifera

Martin & Wilczewski (1970) listed several genera of Foraminifera from the Tses Boulder-Mudstone Member of the Dwyka Group (Keetmanshoop District). These are *Hyperammina. Ammodiscus, Glomospira, Ammobaculites* and *Spiroplectammina* as well as other unidentified forms. Schreuder & Genis (1975) recorded a similar assemblage of Foraminifera from a striated pebble diamictite at Kanabeam 331, Karasburg Basin. The importance of these foraminiferans is that they appear to indicate marine conditions of deposition in this part of southern Namibia during the Permian.

Annelida

Scolecodonts (fossil annelid jaws) were reported, without details from the Tses Boulder-Mudstone Member by Martin & Wilczewski (1970).

Conulariida

Schroeder (1908) reported the discovery at Ganikobis of *Conularia*, a marine organism (possibly a scyphozoan coelentrate but of uncertain affinities) which he thought indicated a Permian age. Range (1912) illustrated a specimen collected at Ganikobis by Gathmann.

Mollusca

The thick-shelled bivalve *Eurydesma mytiloides* has been known from the Namibian Dwyka beds for a long time (Range 1912). Other molluscs reported from the sequence by Martin & Wilczewski (1970) consist of the goniatite *Eoasianites (Glayphyrites)* sp (Du Toit 1916), the gastropod *Peruvispira vipersdorfensis* and the bivalve *Aphanaia haibensis*. All these forms are known from the southern outcrops in Rehoboth, Mariental, Keetmanshoop and Karasberg Districts (Dickins 1961; McLachlan & Anderson, 1973; Heath 1972; Schalk & Germs 1980).

The holotype of *Aphanaia haibensis* Reed 1935, was found by Haughton (Haughton & Frommurze 1928) near Haib (Karasberg District). It consists of a large obliquely elongated mytiliform left valve with only a part of the right valve preserved. The shell is about 85 mm long by about 45 mm wide.

The holotype and paratypes of the gastropod *Peruvispira vipersdorfensis* Dickens, came from Vipersdorf 63 (Mariental District), while additional material was found in Tses Reserve near the main road about 13 km north of Tses Siding. The upper whorl surface of this gastropod is almost straight with the slit-band at the outer edge and approximately vertical. The slit-band is bounded on either side by a distinct ridge, and below it the outline is concave – the concave part being bordered below by a ridge. The outline then joins the base with an arc of low curvature. The columellar lip is distinctly thickened. The species in non-umbilicate and most adult specimens have four whorls, although some have five. Material ranges in height between 8 and 9 mm, in width between 5.5 and 6 mm, and the apical angle ranges between 38° and 46°.

A specimen of the goniatite *Eoasianites (Glaphyrites)* Ruzhencev, was found in a siliceous phosphatic nodule near Schlip (Rehoboth District). Martin *et al.* (1970) assigned it to the subgenus (*Glaphyrites*) and reported that it had 9 whorls and was probably an adult of which the body whorl had broken away.

Brachiopoda

Heath (1966, 1972) illustrated a brachiopod from Hardap 110, but did not describe it in detail. The specimen is probably an example of the bivalve *Eurydesma*.

Bryozoa

Wass (1970, 1972) described some bryozoans *Dyscritella* cf *D. spinigera*, from a locality not far northwest of Mariental (Lane & Frankes 1979).

The specimens on which the record of *Dyscritella* cf *spinigera* (Bassler) is based, were found near Mariental in a calcite-cemented sandstone. The zoaria vary in diameter from 1.08 mm to 1.68 mm, some specimens are oval in section with a width of 1.35-1.40 mm and a length of 1.57-1.75 mm.

Porifera

Sponge spicules were reported from Tses by Martin & Wilczewski (1970) but detailed descriptions have not been published.

Echinodermata

A fragment of starfish was found in a low bluff between Mariental and Hardap (Lane & Frakes 1970).

The specimen is the end of an arm, well preserved but so incomplete that it cannot be assigned to a genus or species. The authors identify it as a member of the family Monasteridae. Heath (1966, 1972) illustrated a virtually complete starfish from Hardap 110, which appears to be the same species as that described by Lane & Frakes. An additional broken specimen has recently been collected from the same site, but it is too fragmentary to add to our knowledge of the species concerned.

Martin (1953) and Martin & Milczewski (1970) record crinoid columnals from the Tses Boulder-Mudstone Member, but details have not yet been published.

Echinoids from near the main road west of Brukaros Siding, north of Tses were recorded by Haughton & Frommurze (1928). They identified the remains as possibly belonging to *Archaeocidaris*. Originally recorded from Dwyka Shales (and thus of Ecca age) this specimen was later considered by McLachlan & Anderson (1973) to have been collected from the Tses Boulder Mudstone, and would thus be of Dwyka age. Martin & Wilczewski (1970) report on the presence of echinoid spines at Tses, but no details are given.

Pisces

Fossil fish have been reported from the Dwyka beds of Namibia since the early part of this century (Gürich 1923; Haughton & Frommurze (1928). Gardiner (1962) provides the most detailed descriptions and analysis of these fossils (Table 2).

Range (1928) summarised the work of Gürich (1923) but identified one of the fish species (genus V by elimination) from the southern Karoo outcrops as *Helichthys loangwae*, although the basis for this identification is not stated. Jubb & Gardner (1975) provide details of repository and discovery horizons of these fish remains. *Namaichthys schroeder* Gürich was first described from Ganikobis (Keetmanshoop District) by Gürich (1923).

Trace Fossils

Arthropod traces from Ai-Ais figured by Abel (1935) and Savage (1971) based on material collected by Haughton, are now preserved at the South African Museum. Anderson (1974) discussed trace fossils from the Warmbad Basin (Ai-Ais, Klipneus and Zwartbas localities). Anderson (1981) dealt with the arthopod trace fossil *Umfolozia* from Klipneus. Other trace fossils were reported from Dwyka beds near Mariental (Lane & Frakes 1970). Horsthemke *et al.* (1990) mention *Umfolozia* in the Dwyka of the Haub Basin. Ledendecker (1992) illustrated ichnofossils from the Dwyka Formation in the Haub Basin which he identified as *Isopodichnus, Diplichnites, Umfolozia sinuosa, Punctichnium namibiense,* and *Glukstadtella cooperi.*

Ecca Group

Strata correlated with the Ecca Group of South Africa are widespread in Namibia (Figure 3),

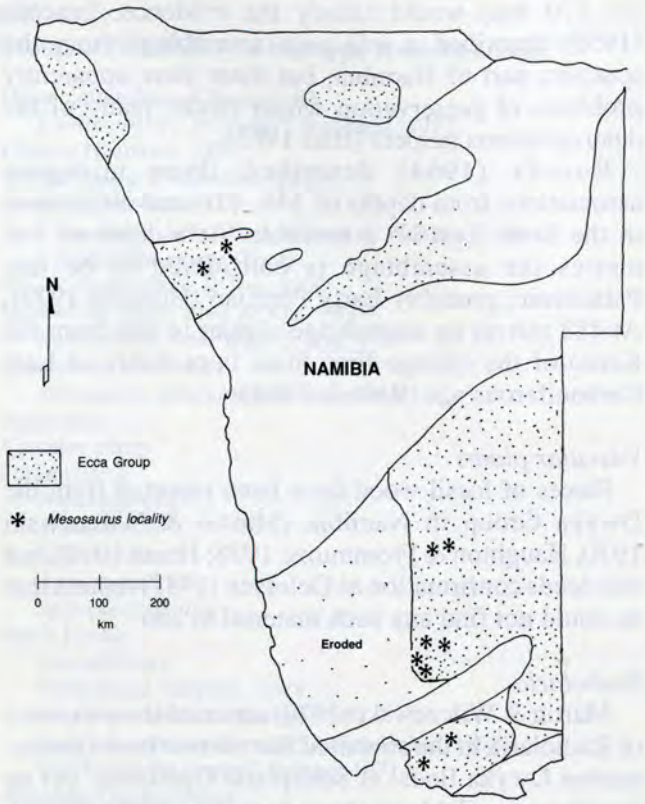

Figure 3. Ecca Group in Namibia. The Ecca Group occurs widely in Namibia, the best exposures being in the south (Kalahari and Karasberg Karoo Basins) and in the northwest (Huab Karoo Basin). *Mesosaurus* is common in these three basins.

occurring in three main outcrop areas: the Kalahari and Karasberg (Warmbad) Karoo in the the south and the Huab Karoo in the northwest. There are also extensive subcrops to the northeast of Etosha.

Numerous plant and invertebrate remains have been collected from the Namibian Ecca Group sediments, which are also rich in stromatolites. Apart from descriptions of *Mesosaurus* and wood, little has been published on these fossils.

Stromatolites

A stromatolite from Kameelhaar (Mariental district) was described by Kräusel (1956). Horsthemke *et al.* (1990) mention that stromatolites are common in the Huab region (Damaraland District) especially in depositional units 5 (Aba Huab Formtion) and 7 (Gai-As Formation). Further information is provided in Horsthemke (1992) and Ledendecker (1992) but detailed descriptions and interpretations have not been published.

Miospores

Ledendecker (1992) illustrated several spores from the Huab Basin Tsarabis formation, including *Calamospora aplata, Vestigisporites* cf *balmei, Vittatina* cf *densa, Gondisporites congoensis* and *Cyclogranisporites* cf *parvus.*

TABLE 3

Fossil Plants from the Huab Karoo Basin (* = holotype from Namibia)

Paracalamites sp. – Doros
Dadoxylon arberi – 16 km S of Quelle Atsab & 5 km west of Awahab Trig. Pt
Taxopitys africana** – Doros Crater
*Solenoxylon wissi** – The holotype is from Rooiberg 517, Damaraland
*Solenoxylon kurzi** – Type specimen is from Rooiberg 517, Damaraland
Solenoxylon oberholzeri – Type is from Rooiberg 517, Damaraland
Solenoxylon sp. – Versteinerter Wald near Khorixas
*Lobatoxylon kaokense** – Holotype was from Rooiberg 517, Damaraland
Megaporoxylon kaokense** – Type specimen from Rooiberg 517, Damaraland
*Kaokoxylon reuningi** – Type material was from Rooiberg 517, Damaraland
*Kaokoxylon durum** – Versteinerter Wald, near Khorixas, Damaraland.

Vascular plants

Fossil wood and leaves are very common in the Namibian Ecca Group sediments, both in the Huab Karoo and the Kalahari and Warmbad Karoo. Kräusel (1928, 1937, 1956a, b, 1959/60) has described much material in detail, while Brown (1977), Rodin (1951), Anderson & McLachlan (1976) and Wiss (1964) provide further information.

The taxa listed in Table 3 are based on fossils from the 'Petrified Forest' west of Khorixas (Kräusel, 1956a) and other Huab Karoo sites such as Doros Crater worked by Range (Kräusel, 1928). Brown (1977) also described material from Doros.

Kräusel (1956b) described fossil wood from the Kalahari Karoo of Mariental and Keetmanshoop Districts (Schlangkopf near Seeheim, Amalia). Other material from Huns, Aurus, Gibeon, Goamus, Mukorop, Berseba, Fish River and Gaibes was also described by Kräusel (1929) (Table 4).

Plant stem fossils, usually casts of the external surface of trunks are common in the Huab area at Verbrandeberg (Damaraland), Ledendecker (1992) recorded an unidentified lycopod, as well as *Cyclodendron leslii*. The latter species was also mentioned as being present in the Karasberg Basin by Schreuder & Genis (1975).

Plant leaves are rare in the Namibian Karoo (Anderson & McLachlan 1976) but *Glossopteris* has been identified at Verbrandeberg, at Gellap Ost (Oelofsen 1981; Anderson & MacLachlan 1976) and at Mukorop (Heinz 1932). The Gellap Ost specimen has a distinct midrib.

An enigmatic leaf-like fossil was found by Oelofsen (1981) on the Farm Aussenkjer (Anderson & McLachlan 1976). It is bilaterally symmetrical with a longitudinal median ridge, which is about 10% of the width of the 'leaf' which itself is 18 mm wide. There is no evidence of secondary venation, but instead there are regular rows of raised dots running obliquely across the impression. The rows of dots, and individual dots, are about 5 mm apart. The outer margin of the impression appears to be irregularly indented, but this may be due to preservation or damage.

Schreuder & Genis (1975) illustrated a sphenophyte leaf (*Phyllotheca*) from sandy shale at the base of the Ecca on Aussenkjer 147 (Karasberg District). The specimen is incomplete, the remaining fragment being some 10.5 cm long and 2.2 cm wide. It has about 10 subparallel 'folds' running along the length of the leaf converging towards the tip. In 1978 *Glossopteris* leaves were collected by Keyser and Smith at the petrified forest site (Smith pers. comm.).

Crustacea

Oelofsen (1981) reported that the crustacean *Notocaris tapscotti* is abundant in the Karasberg and Kalahari Karoo Basins, and at some sites is found in the same beds as the reptile *Mesosaurus*, of which it may have been a food item (Haughton & Frommurze 1928). *Notocaris* has been recorded from Gellap Plateau and the Farm Spitzkop, and Schreuder & Genis (1975) illustrated some material from Aussenkjer 147.

TABLE 4

Fossil Plants from the Kalahari Karoo (* = holotype from Namibia)

Cyclodendron leslii – Goamus
Medullopitys sclerotica** – Weg Huns-Keetmanshoop
*Dadoxylon porosum** – Weg Huns-Keetmanshoop
*Dadoxylon rangei** – Berseba, Weg Huns-Keetmanshoop, Aurus, Road 7 km west of Kalkfontein towards Keetmanshoop, 5 km northeast of Naute towards Keetmanshoop, Keetmanshoop, Itsawisis
*Megaporoxylon scherzi** – Mariental
*Megaporoxylon zellei** – Type specimen from Amalia Mariental District
*Phyllocladopitys capensis** – Ganikobis, Gaibes, Schlangkopf near Seeheim
*Phyllocladopitys martini** – Mariental
Phyllocladoxylon capense – Ganikobis, Goamus, between Tses and Arietites, Mukorop, Berseba and the bed of the Fish River
Abietopitys perforata – Weg Huns-keetmanshoop, Schlangkopf near Seeheim

Mollusca

Haughton & Frommurze (1982) recorded the presence of bivalves and gastropods in Upper Dwyka Shales at Haib, but these may well be Ecca. Ledenecker (1992) recorded two genera, the bivalves *Palaeomutela tanganyikensis* from the Tsarabis Formation, and *Terraia altissima* from the Gai-As Formation.

Pisces

Fish appear to be rare in the Namibian Ecca Group but recently both Oelofsen (1981) and Ledendecker (1992) have recorded scales and teeth. In the Karasberg (Warmbad) Karoo Anderson (1975) documented fish material at Gooie Hoop, and Oelofsen (1981) mentions having found palaeoniscid scales and a bony plate at Aussenkjer. Further fossils were found on the farms Gross Daberas, Asis, and Kirchberg. Ledendecker (1992) illustrated several elasmobranch teeth and bones and actinopterygian bones from the Tsarabis Formation in the Huab Basin. He also found ganoid scales but none of this material has been studied in detail.

Amphibia

McLachlan & Anderson (1973) refer to a fragment of large amphibian bone from Haib (Haughton & Frommurze 1928, 1936). Horsthemke *et al.* (1990) mention coprolites and bone fragments of amphibian in their 'depositional unit 4', equivalent to the Prince Albert Formation. Ledendecker (1992) illustrated some labyrinthodont remains from the Tsarabis Formation, Huab Karoo Basin, one of the few amphibian fossil ever recovered from the Namibian Karoo. The only other known specimen is from the Omingonde Formation (Keyser 1975).

Reptilia

The most common and best preserved vertebrates from the Namibian Karoo rocks are proganosaurian reptiles of the genera *Mesosaurus* (Figure 4) and *Stereosternum* (Oelofsen & Aurajo, 1987). *Mesosaurus* was first recorded from Namibia in 1914 (Stromer 1914; Hennig 1914). The genus *Stereosternum*, well known from Brazil, was recorded from Namibia only recently (Oelofsen & Araujo 1987), its remains having previously been included in *Mesosaurus*. Grote (1984) illustrated disarticulated remains of *Mesosaurus* from Daberas Ost 18, while Schreuder & Genis (1975) illustrated an almost complete specimen from the White Band at Aussenkjer 147.

Von Huene (1925) described what he thought was an isolated mammalian tooth from Doros collected by Reuning, naming it *Archaeotherium reuningi*. Range (1928, 1930) also mentions the specimen in passing, but according to Keyser (1973b), it appears to belong instead to a mammal-like reptile, possibly a cynodont. Keyser (1973b) reported the presence of Dinosauria in the Huab Karoo, 6 km north of Doros, based on a large lumbar vertebra, but detailed descriptions have not been published. Both *Archaeotherium* and the dinosaur are from strata younger than the Ecca.

Figure 4. *Mesosaurus tenuidens* from the White Band at Aussenkjer 147, Southern Namibia. Impression of almost complete skeleton with skull preserved in limestone. Bone has dissolved leaving a natural mould of the skeleton. Scale bar: 50 mm

Trace Fossils

Numerous trace fossils are known to occur in the Namibian Karoo rocks (Haughton & Frommurze 1985) but few have been described. Bather (1927) reported the presence of a U-shaped worm burrow from the Dwyka Shales at Haib, Karasberg District (Haughton & Frommurze 1928, 1936). This fossil was found in the Upper Dwyka Shales, and is thus technically from the

TABLE 5
List of Organisms and their Traces from the Ecca Group in Namibia (* = holotype from Namibia)

Stromatolites

Sporites
Calamospora aplata Bhardwaj & Salujha 1964
Vestigisporites cf *balmei* Hart 1960
Vittatina cf *densa* Anderson 1977
Gondisporites congoensis (Maheshwari & Bose 1969)
Cyclogranisporites cf *parvus* (Lakhanpal Sah & Dube 1960)

Vascular plants
Paracalamites sp. Zalessky
Dadoxylon arberi Seward
Taxopitys africana** Kräusel 1928
Solenoxylon wissi** Kräusel 1956
Solenoxylon kurzi** Kräusel 1956
Solenoxylon oberholzeri** Kräusel 1956
Solenoxylon sp. Kräusel 1956
*Lobatoxylon kaokense** Kräusel 1956
Megaporoxylon kaokense** Kräusel 1956
*Kaokoxylon reuningi** Kräusel 1956
*Kaokoxylon durum** Kräusel 1956
Medullopitys sclerotica** (Gothan 1908)
*Dadoxylon porosum** Kräusel 1928
*Dadoxylon rangei** Kräusel 1928
*Megaporoxylon scherzi** Kräusel 1956
*Megaporoxylon zellei** Kräusel 1956
*Phyllocladopitys capensis** Kräusel 1929
*Phyllocladopitys martini** Kräusel 1956
*Phyllocladopitys capensis** Kräusel 1928
Phyllocladoxylon capense Walton 1925
*Abietopitys perforata** (Gothan 1908)
Filices?
lycopod
Cyclodendron leslii (Seward 1903)
Glossopteris Brongniart 1828
Phyllotheca Brongniart 1828

Trace Fossils
Limulus
Umfolozia Savage 1971
Scolicia
Cruziana
Skolithos Haldeman 1841
Siphonichnus
Diplocraterion or *Teichichnus*
Planolites opthalmoides Jessen 1950

Crustacea
Notocaris tapscotti Broom 1931

Mollusca
*Aphanaia haibensis** Reed 1936
Palaeomutela tanganyikensis Cox 1936
Terraia altissima (Holdhaus 1918)

Pisces
Palaeoniscidae
Elasmorbranchia
Actinopterygia
Ganoidea

Amphibia

Reptilia
Mesosaurus tenuidens Gervais 1864
Stereosternum tumidum

Ecca Group. Anderson (1975) illustrated and discussed limulid tracks, *Koupichnium*, from the Whitehill Formation at Gooie Hoop, north of Vioolsdrif. Oelofsen (1981) mentions trace fossils at Haib and Aussenkjer in the Warmbad Karoo, and at Brandberg. Schreuder & Genis (1975) report a *Limulus* trackway from the boulder shale at Aussenkjer. Some of the Haib *Umfolozia*-type trackways could represent the activity of the crustacean *Notocaris tapscotti* (Oelofsen 1981) because some of the body imprints have such trackways leading up to them. *Scolicia*-like trails occur near the Brandenberg in the Karasberg and Kalahari Karoo Basins. *Cruziana* and *Skolithos* inchnofossils are common in the Karasberg and Kalahari Karoo Basin (Oelofsen 1981). Kingsley (1985), working on cores from drill holes, reported that the genera *Siphonichnus* and *Diplocraterion* or *Teichichnus* occur in the Ecca beds of the eastern part of the Kalahari Karoo Basin. He also mentioned the presence of *Cruziana* and *Skolithos*.

Ledendecker (1992) illustrated a tube-like trace fossil, *Planolites* from the Tsarabis Formation of the Huab Basin.

Omingonde Formation

The Omingonde Formation (Figure 5) is widespread in the Otjiwarongo, Grootfontein and Omaruru Districts. Main outcrops are south of the Waterberg thrust (Lüdke 1970) near Mt. Etjo, Omatakos and north of the Waterberg Plateau.

The first fossil vertebrate discovered in the

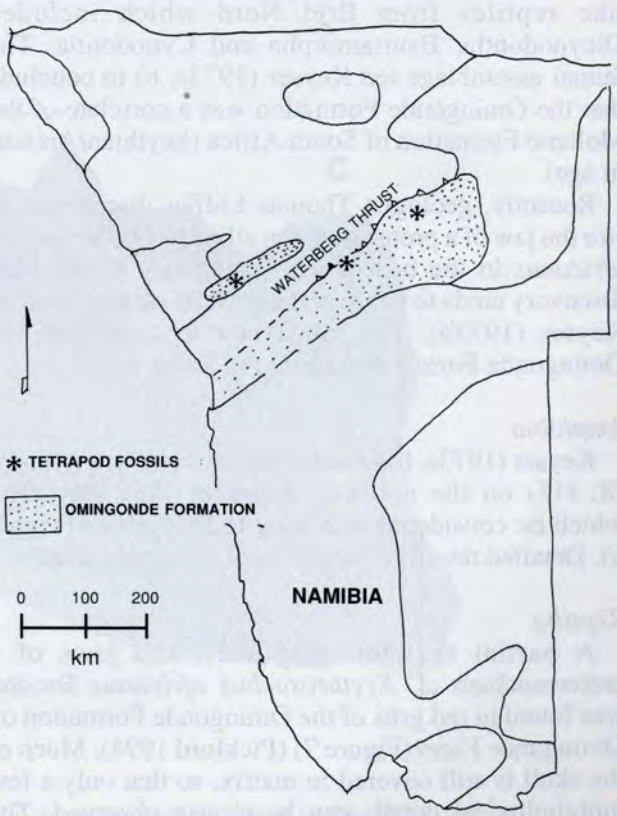

Figure 5. The Triassic Omingonde Formation, Namibia.

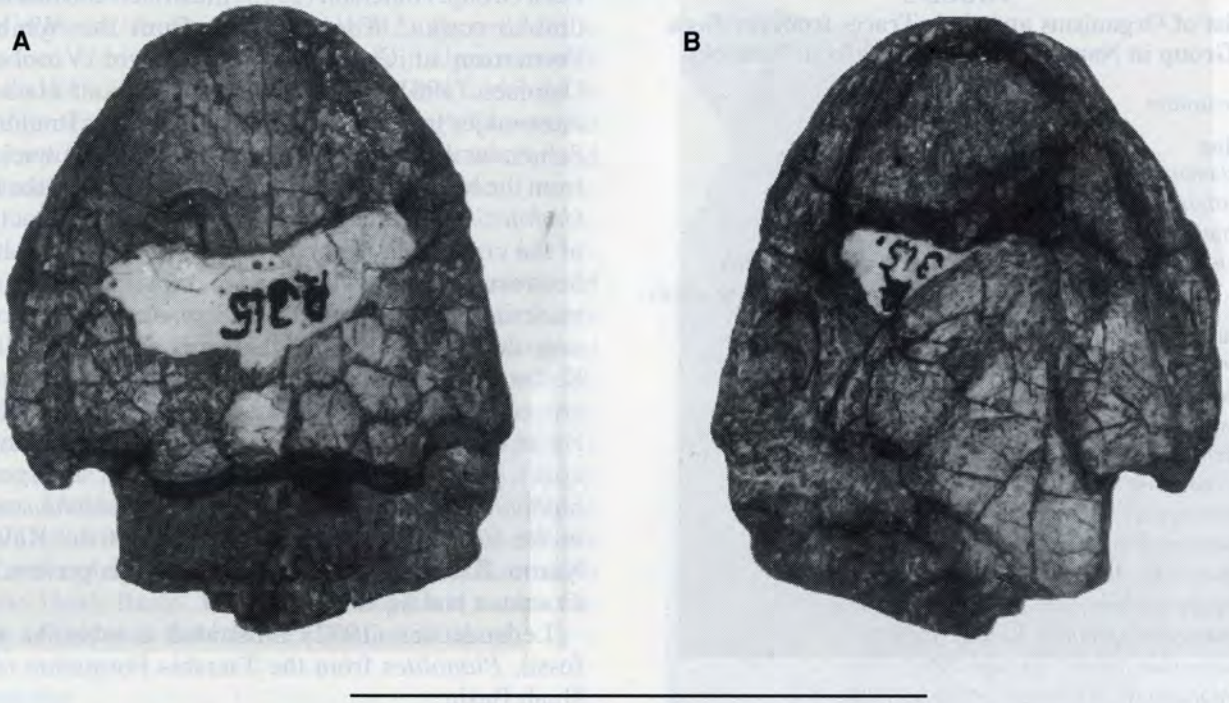

Figure 6. R.315, skull of a small eriopoid amphibian from the Omingonde Formation, northern slopes of Mt Etjo, Central Namibia. **A** – dorsal and **B** – ventral views. Scale bar: 50 mm

Omingonde Formation is considered to have been a reptile skull found on Farm Breitenbach during the 1920's but nothing has ever been published about the specimen, the present whereabouts of which are unknown. Keyser (1973a, b, 1978) recovered a moderately diverse fauna of Amphibia and mammal-like reptiles from Etjo Nord which included Dicynodontia, Bauriamorpha and Cynodontia. The faunal assemblage led Keyser (1973a, b) to conclude that the Omingonde Formation was a correlate of the Molteno Formation of South Africa (Scythian/Anisian in age).

Recently, geologist Thomas Löffler discovered *in situ* the jaw of a proterosuchian allied to *Erythrosuchus africanus* in the bed of the Omingonde River. This discovery tends to confirm the correlation proposed by Keyser (1973b). The fauna now known from the Omingonde Formation is listed in Table 6.

Amphibia

Keyser (1973a, b) found a skull of a small amphibian (R. 315) on the northern slopes of Etjo Mountain, which he considered to belong to Eriopoidea (Figure 6). Detailed descriptions have not been published.

Reptilia

A partial skeleton with skull and jaws of a proterosuchian cf *Erythrosuchus africanus* Broom, was found in red grits of the Omingonde Formation on Omingonde Farm (Figure 7) (Pickford 1994). Much of the skull is still covered in matrix, so that only a few morphological details can be clearly observed. The lower jaws are 62 cm long and 66 mm deep below the

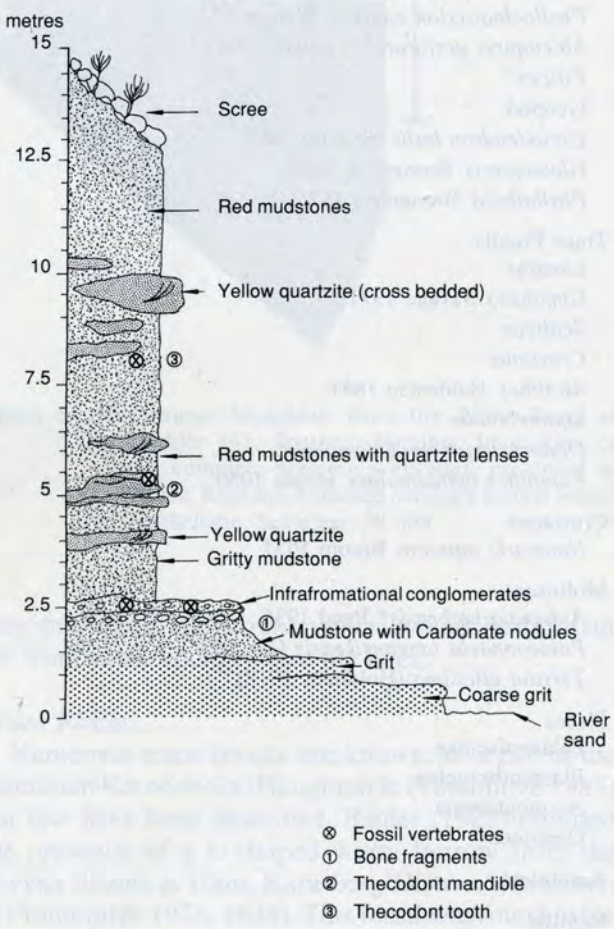

Figure 7. Stratigraphic succession at Omingonde thecodont site.

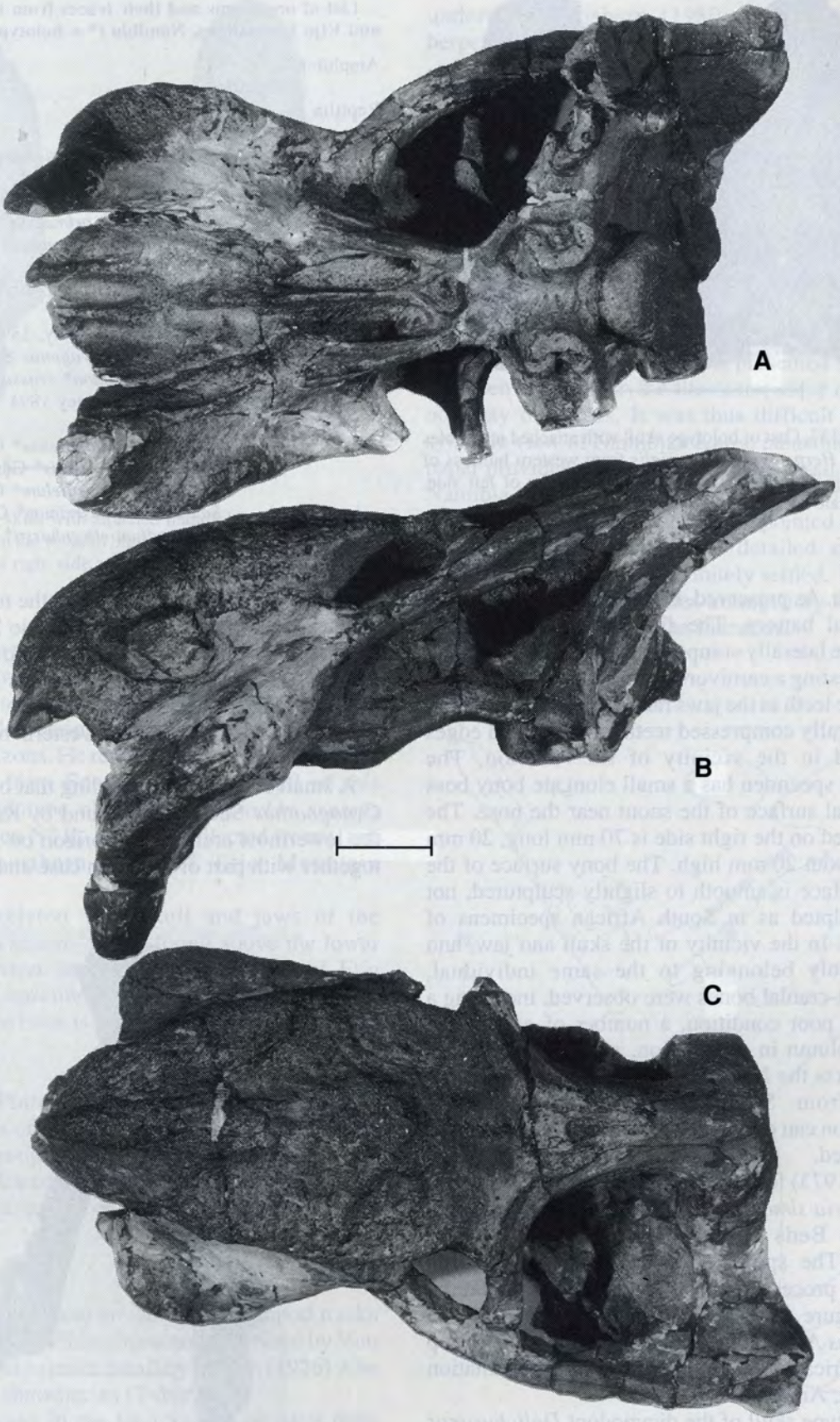

Figure 8. R.313, skull of *Kannemeyeria simocephalus* from the northern slopes of Mt. Etjo, Central Namibia. A – ventral view, B – lateral view of left side, C – dorsal view. Scale bar: 50mm.

Figure 9. R.337, Cast of holotype skull with attached mandibles of *Herpetogale marsupialis* from western buttress of Etjo Mountain. Dorsal and lateral view of left side. Scale bar: 50 mm

TABLE 6
List of organisms and their traces from the Omingonde and Etjo Formations, Namibia (* = holotype from Namibia)

Amphibia
- Eriopoidea

Reptilia
- Proterosuchia
  - cf *Erythrosuchus africanus* Broom 1905
- Dicynodontia
  - *Kannemeyeria simocephalus* Weithofer 1888
  - *Dolichuranus* primaevus** Keyser 1973
  - *Rhopalorhinus* etionensis** Keyser 1973
- Bauriamorpha
  - *Herpetogale* marsupialis** Keyser 1978
- Cynodontia
  - *?Cynognathus* Seeley, 1895
  - *Diademodon tetragonus* Seeley
  - *Titanogomphodon* crassus** Keyser 1973
  - *Trirachodon* Seeley 1894
- Ichnofossils
  - *Saurichnium damarense** Gürich 1926
  - *Saurichnium tetractis** Gürich 1926
  - *Saurichnium parallelum** Gürich 1926
  - *Saurichnium anserinum** Gürich 1926
  - *Tetrapodium elmenhorsti** Gürich 1926

second tooth. As preserved, the lower jaw obscures the upper dental battery. The five teeth rooted in the mandible are laterally compressed and possess serrated edges suggesting a carnivorous life style. The emerged height of the teeth in the jaws ranges up to 50 mm. Four similar laterally compressed teeth with serrated edges were found in the vicinity of the skeleton. The Omingonde specimen has a small elongate bony boss on the lateral surface of the snout near the nose. The knob exposed on the right side is 70 mm long, 20 mm wide and about 20 mm high. The bony surface of the side of the face is smooth to slightly sculptured, not heavily sculpted as in South African specimens of *E.africanus*. In the vicinity of the skull and jaw, and very probably belonging to the same individual, various post-cranial bones were observed, including a humerus in poor condition, a number of gastralia, a vertebral column in articulation, and several ribs. In many respects the Namibian fossil appears similar to material from South Africa, but a detailed determination can only be made after the specimen has been prepared.

Keyser (1973) found a large skull of the dicynodont *Kannemeyeria simocephalus* Weithofer in arenaceous lower Etjo Beds on the northern slope of Etjo Mountain. The specimen (R. 313) has very large caniniform processes and exceedingly wide lateral flanges (Figure 8). This species is known from the *Cynognathus* Assemblage Zone of the Beaufort Group of South Africa and from the Puesto Viejo Formation of Mendoza, Argentine.

The holotype skull of the dicynodont *Dolichuranus primaevus* Keyser was discovered by Keyser (1973) on the southern slopes of a hill north of Etjo Mountain, below the lowermost arenaceous horizon.

The holotype skull of *Rhopalorhinus etionensis* Keyser, was collected by Keyser from the northern slopes of Etjo Mountain between the upper and lower arenaceous horizons of the lower Etjo Beds.

The articulated skull and mandibles (R. 337) (Figure 9) of *Herpetogale marsupialis* Keyser, a small therocephalian, were found above the uppermost arenaceous horizon on the western buttress of Etjo Mountain.

A small lower jaw resembling that of the cynodont, *Cynognathus* Seeley, was found by Keyser (1973) in the lowermost arenaceous horizon on Etjo Mountain, together with part of the brain case and the occiput.

Figure 10. Mandible of *Diademodon tetragonus* (R321) from the Omingonde Formation, northern slopes of Etjo Mountain, Central Namibia. Occlusal view. Scale bar: 50 mm.

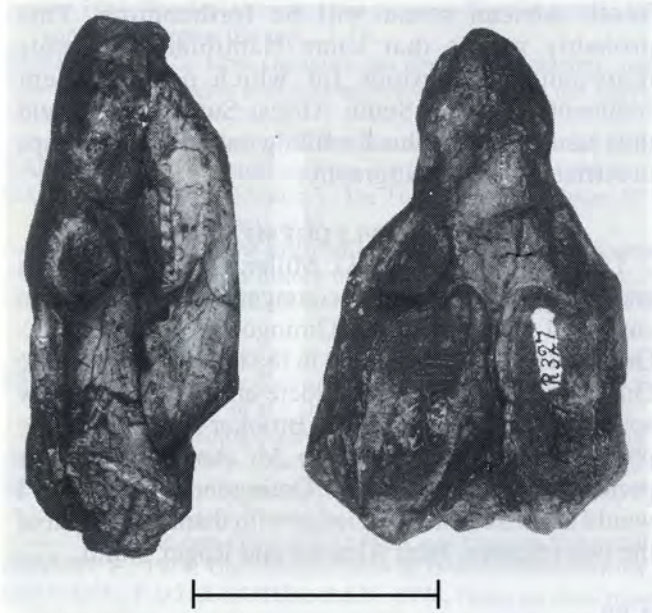

Figure 11. R.327, skull with attached mandibles of *Trirachodon* sp. from the western buttress of Etjo Mountain. Lateral view of right side and dorsal view. Scale bar: 50 mm

A skull, some post-cranial bones and two lower jaws (R. 321: Figure 10) assigned to the cynodont *Diademodon tetragonus* Seeley were found by Keyser (1973) in nodule-bearing shale beds between the two arenaceous horizons. He reported that he could observe no differences from South African material of this species. The holotype of *Titanogomphodon crassus* Keyser, specimen N° R. 322 was collected from a grit bed on the northern slope of Etjo Mountain (Keyser 1973).

A partial skeleton with skull and jaws of the cynodont *Trirachodon* sp was found above the lower arenaceous horizon on the western buttress of Etjo Mountain. The specimen R. 327 (Figure 11) is well preserved but the bone is cracked and deeply impinged by matrix.

Etjo (Plateau) Sandstone Formation

The type area of this formation is the plateau of Mt Etjo. In the group are included aeolianites in the Gamsberg, the Etendeka and Orupembe areas (Figure 12), ranging in age from Late Triassic to Early Cretaceous.

Trace Fossils

At Otjihaenamaperero are abundant tetrapod tracks which were found by Elmenhorst and described by Von Huene (1925) and in more detail by Gürich (1926) who named several ichnospecies (Table 6).

These trackways in the Etjo Sandstone have been interpreted as indicating an upper Carnian to Norian age (Dingle *et al.* 1983).

Tetrapod tracks have also been reported from the Waterberg Plateau (Cosburn 1981) and at Umurumba Omambonde (Wiechmann 1983; Martin 1984; Grote 1985 unpub.) but detailed studies have not been undertaken. Cosburn (1980) listed the following herpetogenera at Waterberg on the basis of ichnofossils – *Massospondylus, Tritylodon, Pachygenelus* and *Gryponyx*, although no details were provided.

Jurassic lavas near Hardap

Swart (pers. comm.) has discovered conchostracans at Hardap, in sediments intercalated in the Jurassic lavas. These small crustaceans, like ostracods, have two shells that are sometimes confused with those of bivalves. The material is currently under study.

SUMMARY

Up to now, much of the data presented in this paper has been scattered in the literature, some of it old and not easy of access. It was thus difficult to obtain a synoptic view of Namibian Karoo palaeontology. This paper provides a gazetteer of Karoo fossil localities in Namibia (Table 1) and lists of taxa reported from the country (Tables 2-6). It should be pointed out that, for some floras and faunas, the detailed stratigraphic positions have not been definitely settled. The lists are thus provisional inventories arranged by stratigraphic positions as reported in the literature.

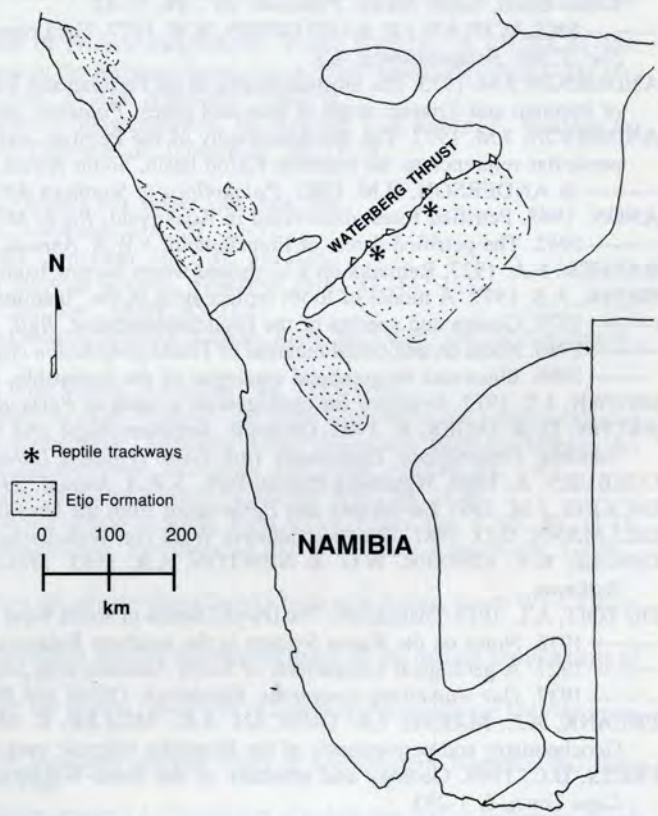

Figure 12. Etjo Formation in Namibia. The aeolian Etjo (or Plateau) Sandstone crops out well in central and northwestern Namibia. The formation comprises aeolianites of various ages ranging from Late Triassic to Early Cretaceous. At serveral outcrops footprints attest to the presence of dinosaurs, including bipedal forms, in Namibia.

It is unfortunate that many of the fossils mentioned in the literature appear to have been lost. Furthermore, the detailed geological context of much of the material was inadequately recorded at the time of collection. Many of the site designations consist of farm names, but Namibian farms tend to be vast, the majority being several thousand hectares in extent. Even if the outcrop or subcrop from which fossils were collected can be identified, the stratigraphic position of the fossils within the outcrop was not always recorded.

Considerable work needs to be done on Namibian Karoo stratigraphy. Up to now, correlations have been made principally southwards with South African Karoo type areas and westwards with Brazilian successions, but it is evident that for some strata, such as the Omingonde Formation and the aelianites in the Etokendeka volcanics, no simple correlations with South African strata will be forthcoming. This probably means that some Namibian sediments represent time periods for which no equivalent sediments occur in South Africa. Such strata would thus assume great value for filling out some of the gaps in African Karoo stratigraphy.

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