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THE PLANT RECORD IN THE DWYKA AND ECCA SERIES (PERMIAN) OF THE SOUTH-WESTERN HALF OF THE GREAT KARROO BASIN, SOUTH AFRICA

by

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ABSTRACT

There is a different relationship between the Dwyka and Ecca Series deposits in two geographically distinct areas of the Great Karroo Basin: in the south-west the White Band terminates the Upper Dwyka Shales, which conformably separate the Dwyka Tillite Stage from the Ecca Series, while in the north-east the Ecca Series, including the Coal Measures, rests directly on the Dwyka glacial deposits or pre-Karroo basement. The stratigraphic correlation of the sequence in the two areas is uncertain as the White Band and Coal Measures sandstones nowhere occur in the same section. The floras from the north-east have been widely described and illustrated; not so those from the south-west. The available information, part of it new, and representative illustrations are presented in this article. The material is too poor to merit formal taxonomic definition, but some general comparisons are possible. The genera *Gangamopteris* and *Noeggerathiopsis* are characteristic of the "*Glossopteris* flora" in the Coal Measures in the north-east; they also occur in the glacial deposits in the south-west. This could be cited in support of isochronous accumulation of the sediments in question. Against this, there is some evidence indicating that *Gangamopteris* may persist *above* the White Band into the Ecca Series in the south-west. The advanced "*Glossopteris* floras" from the Upper Ecca Stages and overlying Beaufort Series in the two halves of the basin appear to be alike. A single incomplete specimen of an "advanced" *Glossopteris* leaf has been found incongruously in the White Band equivalent in South West Africa. It is concluded that reliable correlation between the various Lower Karroo sequences cannot be based on the existing megaplant record.

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INTRODUCTION

In the early literature, the strata of the Dwyka and Ecca Series* in the Cape Province were collectively referred to the "Lower Karroo" (Schenck, 1888; Molengraaff, 1898). We revert to this use of the term, employing it for the Dwyka and Ecca deposits throughout the Great Karroo Basin, because it emphasizes the uncertainty of the basinwide stratigraphic relationship between the two Series. In the south-western portion of the basin the glacial deposits grade upwards into the Upper Dwyka Shales, which terminate with the White Band and are conformably overlain by the Ecca Series Shales. In the north-eastern portion the White Band has not been recognised, and the entire non-glacial sequence is placed in the Ecca Series. The so-called Middle Ecca Coal Measures are developed only in the north-east. Correlation between the non-glacial successions in the two portions of the basin is open to speculation as no single section is known to contain both the White Band, classically

* Although the established terminology (Haughton, 1969) of "Series" and "Stage" denotes a chronostratigraphic framework, the subdivision of the Karroo strata has been based largely on lithological criteria. The South African Committee for Stratigraphy is currently revising the nomenclature (*Trans. geol. Soc. S. Afr.*, 1971), but the revised code has not yet been formally applied to the Lower Karroo strata (which are of Permian age, according to J. M. Anderson, 1973). For this reason we follow the old nomenclature in this article. It should be appreciated, however, that no time connotation is implied.

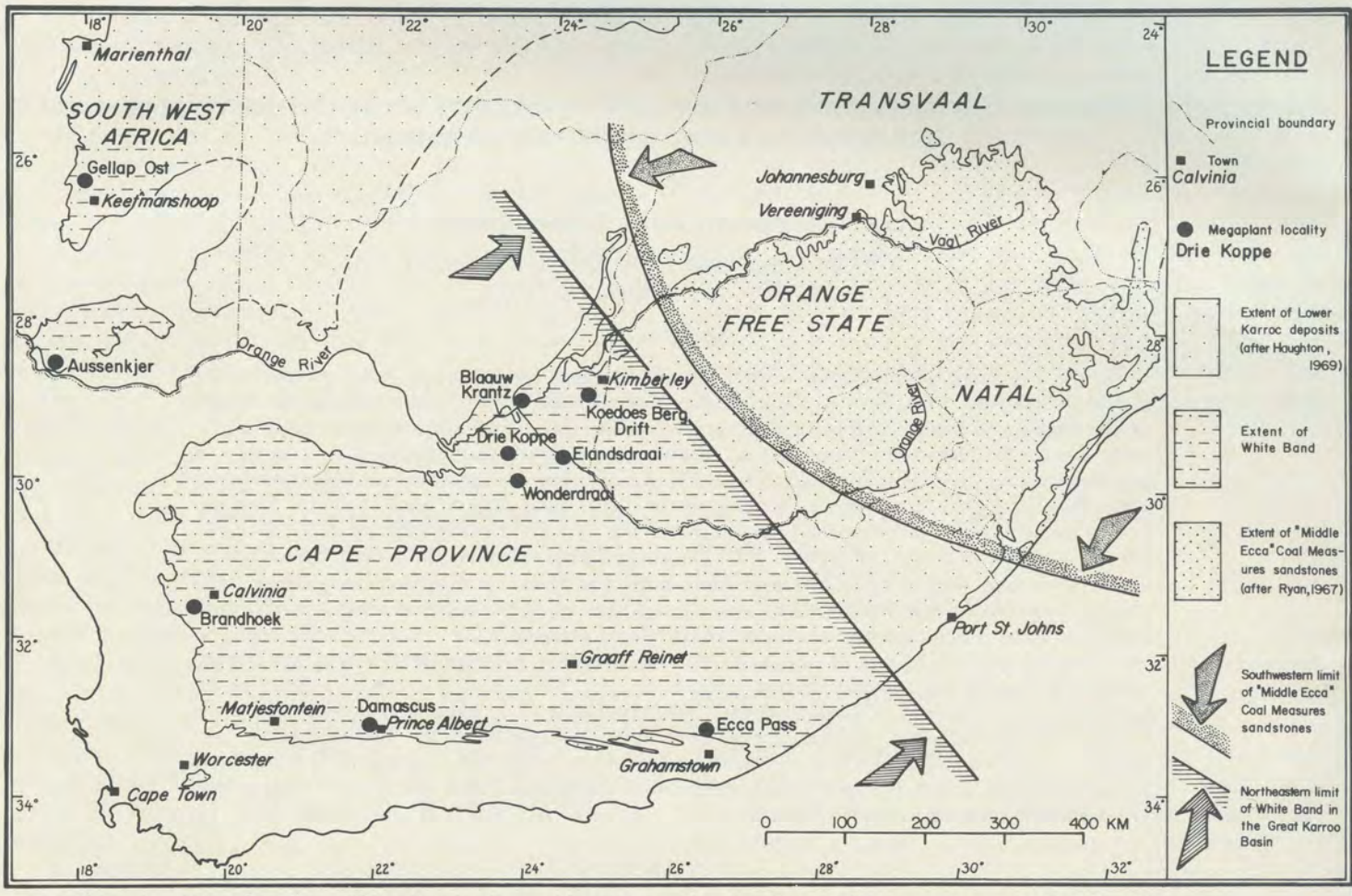

Figure 1. Map of southern Africa showing Lower Karroo megaplant localities in the areas where the White Band is present.

developed in the south-west, and the farthest extension of the sandstones associated with the Coal Measures in the north-east (Figure 1).

Dr. Plumstead has described the "Middle Ecca" Coal Measures in several publications (1957; 1958b; 1961; 1966a), and has contributed to the understanding of the component flora in her classic papers on *Glossopteris* and *Gangamopteris* fructifications (1952; 1956a, b; 1958a; 1962a). Other studies include those of Zeiller (1896), Arber (1905), Seward (1903; 1907), Leslie (1921), Du Toit (1932), Le Roux (1963; 1970; 1975) and Kovács-Endrödy (1974). In contrast, the floras from the south-western portion of the basin have received scant attention, although fossil leaves and other vegetable matter from the south-west were mentioned by several of the pioneering geologists. Feistmantel (1889) and Seward (1903; 1907) described some of the material.

It is the purpose of the present article to update the record of the Lower Karroo floras in the south-western portion of the Great Karroo Basin and to collate the available information. This is undertaken to facilitate comparison with the floras in the north-east.

GANGAMOPTERIS AND *GLOSSOPTERIS* LEAF FORMS

Although we do not present any formal systematic descriptions, it is nevertheless necessary to define the scope of our usage of the generic terms *Gangamopteris* and *Glossopteris*, applied to the ubiquitous Late Paleozoic tongue-shaped leaves of Gondwanaland. We follow tradition in referring to those leaves without a definite midrib as *Gangamopteris* and to those with one as *Glossopteris* (cf. Seward, 1941; Andrews, 1961). The two forms are gradational, and the distinction between them is not always obvious. In both forms the secondary venation, on the lamina, is reticulate.

The two forms are essentially contemporaneous, but *Gangamopteris* is a little more primitive than *Glossopteris:* it is relatively more abundant in the earlier deposits and it disappears well before *Glossopteris,* which survives into the Triassic (Seward, 1941; Du Toit, 1954; Plumstead, 1967; 1972). In the later "*Glossopteris* floras" the individual leaves are generally smaller than in the earlier ones (Plumstead, 1966b). The later floras are also more monotonous in that they contain fewer non-*Glossopteris* elements (Du Toit, 1954; Plumstead, 1969).

MEGAPLANT OCCURRENCES IN THE SOUTH-WESTERN LOWER KARROO STRATA

The lithological succession and the stratigraphic positions of the megaplants are summarised in Figure 2 and their geographical locations are indicated in Figure 1.

Dwyka Tillite Stage

Massive diamictite is an unlikely medium for the preservation of fossil leaves, but Du Toit managed to find two occurrences in the south-western Karroo out-

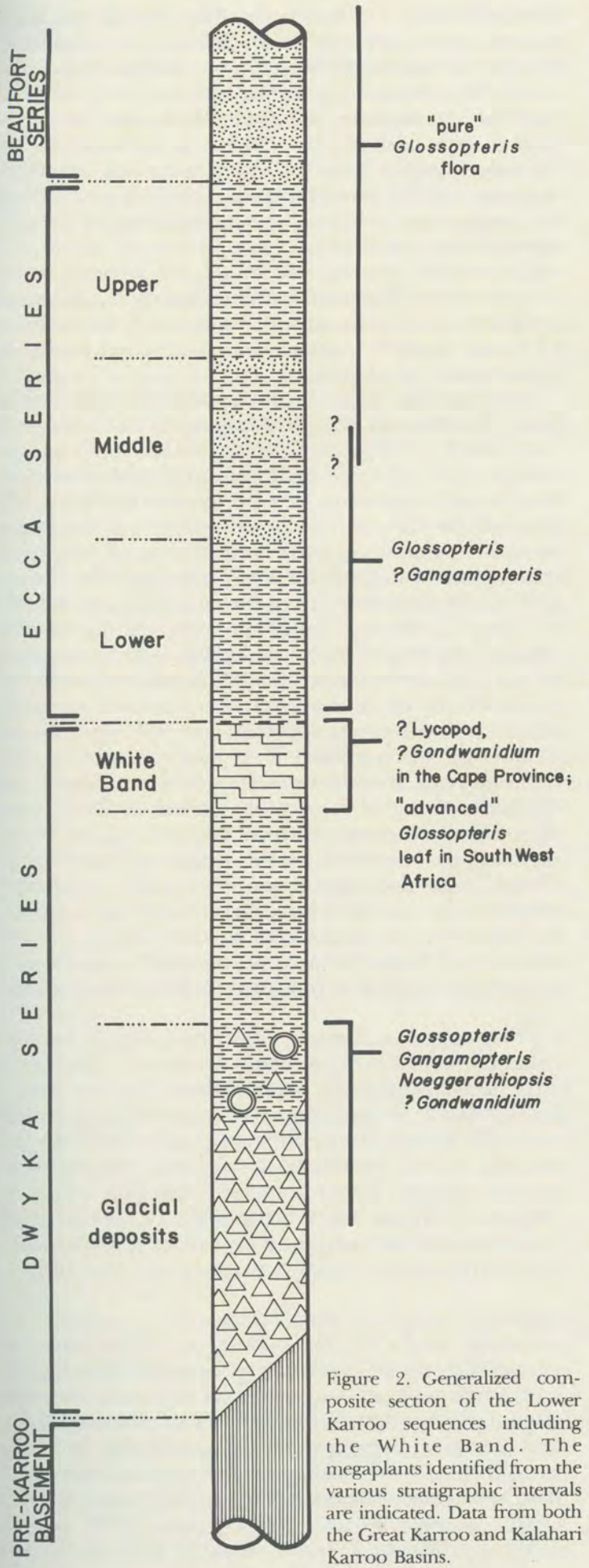

Figure 2. Generalized composite section of the Lower Karroo sequences including the White Band. The megaplants identified from the various stratigraphic intervals are indicated. Data from both the Great Karroo and Kalahari Karroo Basins.

crops. In 1907 (p. 182) he reported that "At Wonderdraai near Strydenberg [± 23°42′E, 30°00′S], . . . wedged in between boulders of rhyolite, were found some fragments of an uncrushed but carbonised plant stem and a portion of a frond of *Gangamopteris*". This was referred to again by Rogers and Du Toit (1909, p. 193). Later Plumstead (1969, Pl. VII, Figure 1) recognised a scrap of *Glossopteris* on Du Toit's original specimen, which is now housed in the South African Museum, Cape Town (catalogue no. K.1135). In his second reference to plant fossils in the massive glacial deposits Du Toit (1929, p. 244) observed that "a pseudo-boulder of quartzite from the tillite at Matjesfontein [± 20°43′E, 33°13′S] in the Cape yielded a poor specimen of either a *Cordaites* or a *Psygmophyllum*". From his tentative identification it would appear that the specimen had non-reticulate, parallel, venation as in *Noeggerathiopsis* (Plumstead, 1964, p. 306).

The final retreat of the glaciers was accompanied by a marine incursion into the Great Karroo Basin (McLachlan and Anderson, 1973a). Fossil wood occurs in abundance with the fish and invertebrates preserved in these glaciomarine deposits (op. cit., Figures 10 and 11). The fossils are usually enclosed in calcareous concretions which provided protection from compression and other damage during diagenesis. This mode of preservation is reminiscent of the northern hemisphere Carboniferous coal balls (Francis, 1961; Schopf, 1975) and the similar occurrences recently described from Antarctica (Schopf, 1970; 1971) and Australia (Gould, 1973) in the southern hemisphere Permian. In the Karroo Basin, however, the plant material was transported into the marine depositional environment; unlike coal balls, the Karroo concretions are not the result of marine inundation of a megafloral community and its debris *in situ*. Hundreds of concretions from the Early Permian glaciomarine horizon in the Great Karroo Basin (see McLachlan and Anderson, 1973b) have been examined, but only one from Blaauw Krantz locality (23°58′E; 29°01′S) on the Riet River, 125 km west-south-west of Kimberley, has yielded any leaves. They have reticulate venation (Figure 5) and no definite midrib, and are therefore referred to the form-genus *Gangamopteris*. Within the flattened ellipsoidal concretion all the leaves have a generally similar orientation (Figure 4): they apparently all originate from the single twig lying along the axis of the concretion (Figure 6).

In 1906 (p. 120) Du Toit recorded that "A fragment of what appears to be a *gangamopteris* was found at Koodoes Berg Drift [24°29′E; 28°57′S] on the Riet River, in a shale containing a few glaciated boulders". This locality is a short distance upstream from the aforementioned Blaauw Krantz locality, and it is probably in the same horizon, although his leaf fragment does not occur in a concretion. Examination of the specimen (Figure 3) reveals that the preserved scrap of foliage is not of the tip of a leaf with evenly spreading venation: there appears to be a midrib running almost parallel with the intact margin, in which case the fragment should be referred to *Glossopteris* or *Gondwanidium* rather than to *Gangamopteris*. The wide spread of the vena-

tion is more compatible with *Gondwanidium* than with *Glossopteris*.

Upper Dwyka Shales Stage

Rogers and Schwarz (1899, p. 89), Du Toit (1906, pp. 119–120), Hälbich (1958, p. 124) and others have recorded indeterminate plant fossils from the Upper Dwyka Shales. McLachlan and Anderson (1973b, p. 418) expressed the opinion, referring particularly to the White Band, that the frequently mentioned "plant remains" are likely to be intrasediment horizontal burrows. Such burrows abound at some levels, but genuine plant material is also definitely present elsewhere.

Unidentified fossil wood has been reported from the Upper Dwyka Shales in general by Woodward (1965, p. 48), and from the White Band near Prince Albert in particular by Haughton *et al.* (1953, p. 23) and Rossouw *et al.* (1964, p. 32). Mr. R. D. F. Oosthuizen of the farm Zwartskraal in this vicinity is in possession of a tree trunk 60 cm in diameter from the White Band in a quarry at Prince Albert.

Seward (1907, p. 484) described a fragment of the lycopod stem *Lepidodendron australe* from a borehole at Elandsdraai (± 24°15′E; 29°40′S) south of Kimberley. Du Toit (1907, p. 182; 1926, p. 215; 1954, p. 280) considered the enclosing shale to be from the Upper Dwyka Stage. We found another specimen south of Kimberley also having a somewhat doubtful stratigraphic position. It is from a shale quarry immediately east of the "Drie Koppe" hills (23°38′E; 29° 41′S). Both the surface topography and the Karroo strata in the area are almost horizontal, which renders the interpretation of the stratigraphic position of isolated outcrops difficult as the relative position of the White Band cannot be readily determined. On the 1:1 000 000 Geological Map of the Republic of South Africa (1970) both localities fall well within the Dwyka Series. No more detailed map is available. The leafy fragment on the recently found specimen from Drie Koppe is itself somewhat contentious. The venation is not reticulate as in *Gangamopteris* and *Glossopteris;* it is parallel, spreading slightly, reminiscent of *Noeggerathiopsis* (Figure 11). The outline of the fragment is generally leaf-like, but there is lamina preserved on each of two, or maybe more, superimposed levels. The puzzling feature is that the direction of the parallel venation is not quite constant. If there is only a single leaf involved, it must have been furled so that its long margins overlapped; if there is more than one leaf represented, it is possible that it was a shoot tip in which the individual leaves had not yet spread apart.

Schwarz (1912, pp. 151–152) noted that "In the Upper Dwyka Shales there have been found in Kimberley and Calvinia a number of remains of a little reptile *Mesosaurus,* while *Glossopteris* occurs sparingly". This could be a reference to *Glossopteris* in the White Band. Du Toit (1926, p. 215; 1954, p. 279) certainly listed *Glossopteris* sp. from the White Band near Kimberley. Engelbrecht (1961, p. 109) reiterated the report, but he did not confirm the occurrence in his detailed description of the geology of an area in the vicinity (1973). Unfortunately the original specimen cannot be traced: it is in neither the Alexander McGregor Memorial Museum in Kimberley nor the South African Museum in Cape Town, where most of Du Toit's collections are currently housed (A. J. B. Humphreys and M. A. Cluver, pers. comm.). We recently found a scrap of leaf lamina with reticulate venation on the farm Damascus (21°57′E; 33°13′S), 3 km west of Prince Albert. The intact margin is strongly curved, and there is evidence of the existence of a midrib on the opposite side (Figure 13). If the specimen is part of a *Glossopteris* leaf the overall shape would appear to have been unusually squat. It seems more probable that it is a single pinnule of a leaf similar to the fern-like *Gondwanidium*.

Another interesting specimen was found in the White Band by Mr. R. D. F. Oosthuizen on the farm Brandhoek (± 19°32′E; 31°36′S), 25 km south-west of Calvinia. It is a twice dichotomising twig apparently covered in short spiny "leaves" or bracts (Figure 12). Towards the base almost the entire width of the twig is occupied by eight or more vertical rows of nearly circular "scars" and the "leaves" may even be absent; towards the three free tips of the twig a thin central axis or "stem" becomes apparent, although the overall width of the twig ("leaves" included) continues to taper evenly. The central axis occupies about one eighth of the width of each of the terminal branches. The closely set "leaves" diverge at approximately 45°. The free tips of the twig are rounded. There is the suggestion of a line of circular bodies between successive "leaves" on the left hand side of the terminal branch on the extreme right. The diameter of these circular bodies is approximately one third of the length of the adjacent "leaves". The detail is too poorly preserved to establish whether any of the terminal branches were indeed fruiting cones or not. Detail in the "leaf scars" and elsewhere is likewise absent, so the identity of the twig as lycopod, conifer or bryophyte must remain conjectural.

Even more enigmatic are the "fucoid straps" collected from the White Band by Mr. B. Oelofsen of Stellenbosch University. Some of these "fucoids" have a blocky surface texture (Figure 17), superficially reminiscent of *Vertebraria* roots; others are almost smooth. The smooth variety frequently has a blunt rounded end, and occasionally there is a coarse, apparently reticulate, "venation" (Figure 16). Whether these Problematica are in fact of vegetable origin is not certain. Even if they are, their identity remains obscure.

Ecca Series

Rogers and Du Toit (1909, p. 199) listed the equisetalian stems *Schizoneura* sp. and *Phyllotheca* sp., the seed *Cardiocarpus* sp. and the leaves *Glossopteris browniana* Brongt., *Gangamopteris cyclopteroides* var. *attenuata* Feistm. and *Cordaites (Noeggerathiopsis) hislopi* Bunb. from the Ecca Series in the Cape Province. Equisetalian stems had been previously recorded by Rogers and Schwarz (1902, p. 109), Rogers and Du Toit (1903, p. 30), Schwarz (1905, p. 289) and Seward (1903, p. 79) and

then by Rogers (1925, p. 19). The *Cardiocarpus* seeds were found in an Ecca outlier near Worcester station in the south-western Cape Province by Schwarz (1905, pp. 288—289) and named by Seward, apparently in an unpublished communication. An example of a possibly similar seed was recently found in the Lower Ecca Stage west of Grahamstown by Mr. C. S. Kingsley (Figure 10).

Along with the *Cardiocarpus* seeds, Schwarz (loc. cit.) found "many fragmentary kinds of *Gangamopteris* and *Glossopteris*" near Worcester, as well as some *Phyllotheca* from another locality in the vicinity. Seward (1903) described at least some of this material. He provided an illustration of a scrap of lamina which he identified as being probably *Glossopteris browniana* Brongn. var. *indica*. He also recognised "One small and very obscure fragment . . . [which] is no doubt a fragment of *Gangamopteris;* it agrees closely with Feistmantel's (1889) figure of *G. cyclopteroides* var. *attenuata*".

Feistmantel (1889) described and figured *Gangamopteris cyclopteroides* var. *attenuata* Feistm. and *Noeggerathiopsis hislopi* Feistm. from the "Kimberley Shales". The specimens were supplied by Moulle (1885, p. 41). Although the local "Kimberley Shales" are part of the basinwide Ecca Series (Corstorphine, 1899, p. 24), Moulle did not actually specify in his book that the leaves were indeed from the Kimberley Shales as such: he merely recorded the occurrence of the leaves in his description of the rock sequence at Kimberley and in the Orange Free State. The leaves are mentioned in the sub-section in which he defined the change into the "Upper Karroo" Stormberg Series at the top of the stratigraphic column. This tends to imply an origin from the Beaufort Series which intervenes between the Ecca and Stormberg Series. Another, more likely, possibility is that the leaves might have been collected from the Ecca Series substantially north of Kimberley, beyond the limit of the White Band; they certainly are reminiscent of the typical Coal Measures leaves found at Vereeniging on the northern border of the Orange Free State.

The third species of leaf, *Glossopteris browniana* Brongn., which was identified by Feistmantel (1889) from the south-western portion of the Great Karroo Basin, has a somewhat more precise geographic location: the material was provided by Dunn (1886, p. 11) from Camdeboo, south-east of Graaff-Reinet. It is not clear from the original description whether the specimen(s) came from the upper Ecca or the overlying Beaufort Series, but the distinction is not particularly significant as in that area very similar *Glossopteris* leaves occur in both Series.

Glossopteris in the Ecca Series has been mentioned quite frequently in the geological descriptions of the south and western Cape Province (Rogers and Schwarz, 1902, p. 109; Rogers and Du Toit, 1903, p. 30; Du Toit, 1926, p. 274; Schwarz, 1905, p. 288; Rogers, 1925, p. 19; Mountain, 1946, p. 22; Haughton *et al.*, 1953, p. 28), and one fragment, not including the midrib, was illustrated by Seward (1903, Pl. XIII, Figure 1). There are fewer reports of *Gangamopteris* from the south-west portion of the Great Karroo Basin (Rogers and Du Toit, 1903, p. 30; Schwarz, 1905, p. 288, *vide ante)* and no illustrated example. In his current detailed investigation of the Ecca Series in the eastern Cape Province, Mr. C. S. Kingsley of Port Elizabeth University has, to date, seen only *Glossopteris* (Figures 7–9), no *Gangamopteris*. He reports that in his study area recognisable leaves occur in the Middle and Upper Stages of the Ecca Series but not in the Lower Stage (which includes the Upper Dwyka Shales and White Band) (pers. comm., Ph.D. in prep.). Kingsley's observations corroborate the assessment made by Haughton *et al.* (1953, p. 28).

Silicified wood has been widely reported from the Ecca Series in the south-western portion of the Great Karroo Basin (Schenck, 1888, p. 230; Rogers and Schwarz, 1902, p. 109; Rogers and Du Toit, 1903, p. 29; Du Toit, 1907, p. 183; 1926, p. 274; Rogers, 1925, p. 19; Mountain, 1946, p. 22; Rossouw *et al.*, 1964, pp. 35, 37). None of it appears to have been formally described, although it is frequently colloquially referred to *Dadoxylon* sp.

COMPARABLE MEGAFLORAS FROM SOUTH WEST AFRICA AND SOUTH AMERICA

The characteristic fossil reptile genus *Mesosaurus* which occurs in the White Band of the south-western portion of the Great Karroo Basin also occurs in South West Africa and South America (Du Toit, 1954, pp. 335, 354). It is generally taken to indicate approximately simultaneous accumulation of the entombing sediments. As such, at least a superficial comparison of the south-western Lower Karroo megafloras with those close above and below the *Mesosaurus* zone elsewhere is indicated.

Rigby (1970) reviewed the plant fossils from the relevant strata of the Parana Basin in Brazil, South America. His species list shows that the flora in the Guatá Subgroup underlying the White Band equivalent Irati Formation is more diverse than in the Estrada Nova Formation overlying it, with five *Gangamopteris* spp. in the former and only two in the latter. From within the Irati Formation itself he listed three species of wood (Kräusel and Dolianiti, 1958), but no leaves. However, according to Bigarella and Salamuni (1967, p. 66), Pinto (1955) found a *Glossopteris* leaf in strata which Machado and Castanho (1956) assigned to the Irati Formation. From Argentina, Harrington (1967, pp. 998—999) recorded an horizon containing *Glossopteris, Gangamopteris* and *Noeggerathiopsis* species, which is both under- and overlain by *Eurydesma* beds. The lamellibranch genus *Eurydesma* is characteristic of the latter stages of the Paleozoic glaciation throughout the former Gondwanaland (Dickins, 1961).

The salient comparison between the fossil plants on either side of the Atlantic Ocean dates back to Du Toit, 1926, p. 278:

> "The Rio Bonito Group [now a Formation within the Guatá Subgroup] contain coals and have yielded an abundant flora including *Gangamopteris, Glossopteris, Lepidodendron, Sigillaria,* etc., strikingly like

that of the [north-eastern] Ecca Series.

It should be noted though that in South America this plant-bearing stage lies below the zone of *Mesosaurus* . . ."

Coals are also developed *below* the *Mesosaurus* horizon in the Kalahari Karroo Basin of South West Africa (see Figure 1) (Martin, 1953). A catalogue of the associated plants is not available, but Kräusel (1956) did describe three genera and species of silicified wood from the Upper Dwyka Shales near Marienthal and Keetmanshoop. These are generically different from those he described from the Irati Formation in South America, and from that apparently identified by Seward from the Ecca series in the Great Karroo Basin (Du Toit, 1926, p. 274).

Mr. B. Oelofsen of Stellenbosch University recently found portion of a *Glossopteris* sp. leaf in the *Mesosaurus*-bearing strata in the Kalahari Karroo Basin while he was collecting specimens of the little reptile. The leaf is from the farm Gellap Ost (± 18°00′E; 26°30′S) north-west of Keetmanshoop. It has a distinct midrib, and the secondary veins run nearly perpendicular to the midrib (Figure 14). These features are indicative of an "advanced" form of *Glossopteris* (Kovács-Endrödy, pers. comm.)

Mr. Oelofsen also found what appears to be a plant impression in the White Band on the farm Aussenkjer (± 17°30′E; 28°30′S) in the Warmbad Basin. Superficially it is leaflike, being bilaterally symmetrical with a longitudinal median ridge (Figure 15). The median ridge occupies approximately one tenth of the total width, 18 mm, of the impression. There is, however, no evidence of secondary venation. Instead there are regular rows of raised dots running obliquely across the impression; they are uninterrupted by the median longitudinal ridge. The rows of dots and the individual dots in each row are both approximately 5 mm apart. The outer margins of the impression appear to be irregularly indented, but this is probably the result of fracture along the margins during parting. Neither base nor tip of the structure is present. Interpretation is problematic. The raised dots might feasibly have been fern sori, but the absence of venation in the lamina tends to detract from interpretation of the structure as a leaf. Another possibility is that the structure is a flattened fleshy stem or reproductive cone which had a firm central column and firm protuberances on its outer surface. This suggestion is not entirely satisfactory either as the arrangement of the dots is too completely regular to represent protuberances from both surfaces of the perfectly two-dimensional "compression".

MEGAFLORAL SUCCESSION IN THE NORTH-EASTERN PORTION OF THE GREAT KARROO BASIN

Dr. Plumstead (1966a, b; 1967; 1969; 1973) has outlined the megaplant succession from the north-eastern portion of the Great Karroo Basin. The following is a brief summary of her zonation. In boreholes in the northern Orange Free State she recognised a pre-*Glossopteris* zone, containing lycopods only, in the transition beds between the Dwyka Tillite Stage and the overlying Middle Ecca Stage. Apparently above this, in other boreholes farther north, she distinguished a proto-*Glossopteris* zone containing moss and various leaves, the majority of which resemble *Gangamopteris*. Although examples with occasional reticulation are encountered infrequently, the venation generally shows bifurcation only, no reticulation. These two basal zones are interbedded with "fluvioglacial" deposits, but the evidence for direct glacial depositon has not been unequivocally established. Leslie (1921, p. xxiii) reported what he considered to be undoubted evidence of plant fossils in the actual glacial conglomerate exposed near Vereeniging: he found well-preserved *Gangamopteris* leaves in a shale 7,5 cm from the basement between large erratic boulders lying on the pre-Karroo surface. That particular outcrop is no longer in existence, but when Nel and Jansen (1957, p. 28) mapped the area in detail they observed that the "conglomerate, which occurs in places at the base of the Karroo beds, . . . has the character of an ordinary, coarse conglomerate rather than a boulder-clay or tillite". The inference is that Leslie's nearly 300 mm long *Gangamopteris* leaves (some of which are illustrated by Plumstead, 1969, Pl. VII 2, 3, 4) at least are not necessarily representative of the Dwyka glacial flora in the north-east. They are probably merely part of the non-glacial Middle Ecca Coal Measures zone, albeit an early part. The flora of this mixed *Glossopteris* zone contains a variety of leaf forms (e.g. *Gondwanidium, Noeggerathiopsis*) besides *Gangamopteris* and *Glossopteris*. The final Palaeozoic *Glossopteris* zone, firmly established in the Beaufort Series, is marked by an overwhelming preponderance of *Glossopteris*, without any *Gangamopteris* or *Noeggerathiopsis* being involved.

STRATIGRAPHIC OCCURRENCE OF *GANGAMOPTERIS* AND *GLOSSOPTERIS* IN THE TWO PORTIONS OF THE GREAT KARROO BASIN

In the Middle Ecca Stage in the north-eastern portion of the Great Karroo Basin fossil leaves are beautifully preserved *en masse* at some localities (e.g. Vereeniging, described by Leslie, 1921). With the possible exception of the Upper Ecca Stages, similar banks of leaves have not yet been reported from the Lower Karroo strata in the south-western portion of the Basin. The explanation probably lies in the differing depositional conditions which prevailed in the two areas. In the north-east the leaves appear to have accumulated in quiet lake or marsh environments, within or not too distant from the thriving *Glossopteris* forests; in the south-west leaves occur only sporadically in more remote offshore deposits (Ryan, 1967). Whatever the cause, it does seem that only strenuous effort and good fortune will yield plant collections adequate for reliable definition of the floras in the south-western Lower Karroo deposits. A detailed comparison between the floras of the north-eastern and south-western portions

of the Great Karroo Basin is therefore not feasible at this stage. Some generalisations are nevertheless possible:

1. In the south-western portion of the Basin and in South America (Harrington, 1967) both *Gangamopteris* and *Glossopteris* occur in Dwyka glacial deposits; in the north-eastern portion there are no confirmed records of these leaves in unambiguous glacial deposits.
2. *Gangamopteris* sp. leaves are characteristic of the Middle Ecca Stage in the north-east. In the south-west these leaves certainly occur below the White Band, less certainly above it, although they have been reported from both above and below the White Band equivalent in South America (Mendes, 1967; Rocha-Campos, 1967; Rigby, 1970).
3. The record in the Lower and Middle Ecca Stages in the south-west is very poor. By the Upper Ecca Stage only *Glossopteris* leaves, no *Gangamopteris*, are present. This seems also to be the case in the north-east (Plumstead, 1966b, p. 8).

CORRELATION BETWEEN THE SOUTH-WESTERN AND NORTH-EASTERN PORTIONS OF THE GREAT KARROO BASIN

There has been controversy about the correlatives of the so-called "Middle Ecca" Coal Measures of the Transvaal and Natal, in the north-eastern portion of the Great Karroo Basin, ever since their discovery towards the end of the last century. The early correlations suggested by Dunn (1886) and Draper (1897) were naturally with the Molteno Stage of the Stormberg Series because these are the only strata in the Cape Province characterized by any marked development of coal. When it was appreciated that the floras in the Transvaal and Natal Coal Measures were clearly older than those in the Molteno coal horizons (Feistmantel, 1889; Seward, 1897), Dunn (1898; 1900) argued in favour of correlation of the former with the Ecca Series in the Cape Province. This conclusion was accepted by Corstorphine (1903; Hatch and Corstorphine, 1905), but not by Molengraaff (1904), who preferred to correlate the Transvaal Coal Measures with the Beaufort Series in the Cape Province. Each author cited fossil plants in support of his preferred correlation. Mellor (1906) discussed this anomaly, regretting that practically all the fossils available as evidence are plant remains. He established that the Coal Measures strata contained no evidence of contemporaneous glacial activity, and decided that correlation with the Beaufort Series was most likely. Du Toit reviewed the situation in 1918. He (p. xx) pointed out that the varied Ecca sediments in the southern Cape Province graded into an argillaceous facies in the northern Cape Province, and that the Coal Measures in Natal graded southwards into a similar argillaceous facies. This correlation has been followed in most subsequent texts (Du Toit, 1926; Haughton, 1969; Rust, 1973; Cooper, 1974; A. M. Anderson, 1975). Unfortunately the Ecca deposits in the southern Cape Province do not link directly with those along the east coast as that corner of the Great Karroo Basin is truncated by the Indian Ocean. It is in that critical interval that the White Band disappears. Early observers (Rogers and Schwarz, 1901; Du Toit, 1920; 1946) reported the occurrence of strata reminiscent of the White Band directly overlying the massive Tillite Stage near Port St. Johns. However, the gray Upper Dwyka Shales which underlie the White Band in the remainder of the Cape Province are missing, and the characteristic White Band fossils (the reptile *Mesosaurus* and *Notocaris* sp. crustaceans) have not yet been found in that area. It therefore seems best to regard the existence of White Band at the northern side of the truncation with reservation. This renders the traditional correlation of the argillaceous Ecca facies in the Northern Cape with similar facies in Natal somewhat less tenable. The currently more fashionable theory is that the so-called Middle Ecca Coal Measures in the north-east were isochronous, not with the Ecca Series in the south-west, but with some part of the Dwyka Series (Kent, 1938; Van Eeden, 1961, 1973; Plumstead, 1962b; McLachlan and Anderson, 1973a; J. M. Anderson, 1973). Unfortunately the outcrops along the north-western edge of the Basin are too poor to provide a decisive solution; nor is there a borehole anywhere in the Basin known to have intersected both Coal Measures sandstones and unequivocal White Band.

We return, in slightly different context, to Mellor's (1906) lament that the megaplants are too ill-understood to provide much indication one way or the other: in the intervening seventy years there has been little improvement in the definition of the Lower Karroo megafloras of the Cape Province, covering the south-western portion of the Great Karroo Basin. At least it is clear now that the Beaufort Series, with its more advanced "pure" *Glossopteris* flora, overlies the Ecca Series in the north-east and that a similarly advanced flora occurs in the Upper Ecca Stage and Beaufort Series in the south-west: correlation of the Coal Measures with the Beaufort Series thus needs no longer to be considered seriously. The present controversy centres on the option of correlation with the Dwyka or Ecca Series in the south-west. At the generic level, plants (*Gangamopteris*, *Noeggerathiopsis*) characteristic of the "Middle Ecca" Coal Measures in the north-east were certainly established during the Dwyka glaciation in the south-west, but there is some indication that they may have persisted above the White Band into the Ecca series as well. If so, it is possible that within the timespan represented, given suitable environmental conditions at any locality, coals with closely similar floral composition might equally well have accumulated either before or after White Band formation. There is a further complication: presently available information does not preclude the possibility that the White Band and *Mesosaurus* may be diachronous. The presence of "advanced" *Glossopteris* in the *Mesosaurus* horizon in South West Africa could be taken to indicate correlation with the Upper Ecca Stages or Beaufort Series in the Great Karroo Basin. However, no reliance can be placed on a single, incomplete leaf, particularly as similar "advanced" forms also occur in the

Middle Ecca Coal Measures sequence (cf. Plumstead, 1956a, Pl. 6) where the "primitive" *Gangamopteris* is still abundant.

It must be regretfully concluded that, with the currently available evidence, megaplants contribute little towards the resolution of the correlation controversy outlined above.

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EXPLANATION OF ILLUSTRATIONS

PLATE I

Figure 3. Scrap of lamina found by Du Toit (1906) in shale near the top of the Dwyka Tillite Stage at Koodoes Berg Drift. The leaf appears to have torn along the midrib on the left. The venation lineation spreads towards the margin on the right. Even if the margin on the right is not intact, the spread of the venation is too wide to conform with the typical elongate *Glossopteris* leaf form; it is more likely that the fragment is one pinnule from a *Gondwanidium*-like frond. (×2, South African Museum specimen number K1136.)

Figure 4. Stereopair of the concretion containing leaves from Blaauw Krantz locality. It has been split open along the widest section of the flattened concretion. (×0,5, Bernard Price Institute, B.K. 7.)

Figure 5. Detail of reticulate venation and ill-defined midrib from one of the *Gangamopteris* leaves in the Blaauw Krantz concretion (×2.)

Figure 6. Polished section, perpendicular to the section shown in Figure 4, of the Blaauw Krantz concretion. The dark rimmed oval feature in the top right hand quadrant of the picture is a stem in which the cellular structure is preserved. The smooth curving line at the bottom of the picture is the outer surface of the concretion. The sinuous hair-fine lines between it and the stem are leaves in cross section (×1.)

Figure 7. Tip of *Glossopteris* leaf from the Middle Ecca Stage at Ecca Pass, north of Grahamstown. It has a persistent midrib and the secondary veins leave it at a wide angle. The meandering lines crossing the leaf are intrasediment burrows. (×2, C. S. Kingsley, field specimen number 70/7/1.)

Figure 8. Stereopair of two *Glossopteris* leaves from the Upper Ecca Stage at Ecca Pass, north of Grahamstown. (×0,5, C. S. Kingsley, field specimen number 75/63/1.)

Figure 9. Detail of the midrib and reticulate secondary venation of one of the leaves shown in Figure 8 (×2).

Figure 10. Well-preserved seed from the Lower Ecca on the farm Bosfontein, west of Grahamstown. The body of the seed has a peaked apex (pointing towards the top of the page in the photograph). A marginal flange, probably a wing, surrounds the body of the seed. It is widest towards the apex and absent at the base where the seed was attached to the parent plant. (×2, C. S. Kingsley.)

PLATE II

Figure 11. Leaf-like impression with spreading venation from Drie Koppe, probably from the Upper Dwyka Shales. (×1, Bernard Price Institute, D.K. 1.)

Figure 12. Dichotomising leafy twig from the White Band at Brandhoek. (×1, R. D. F. Oosthuizen, specimen number G 38.)

Figure 13. *Gondwanidium*-like pinnule from the White Band on the farm Damascus. The reticulate venation spreads from the torn edge on the left towards the smooth curving intact margin on the right. (×2, Bernard Price Institute, Da. 1.)

Figure 14. Basal portion of "advanced" *Glossopteris* leaf from the *Mesosaurus* horizon on Gellap Ost in South West Africa. The midrib is well defined. (×2, B. Oelofsen, field collection number USS 6/4/4.)

Figure 15. Problematic structure from the White Band on Aussenkjer in southern South West Africa. (×1, B. Oelofsen, field collection number USS 6/6/2.)

Figure 16. Problematic "fucoid strap" from the White Band near Calvinia. The tip, near the top of the picture, is bluntly rounded. There is a suggestion of a coarse reticulate venation towards the top/left. (×1, B. Oelofsen, field collection number USS 1/10/4.)

Figure 17. Problematic "fucoid strap", with "blocky" surface texture, from the White Band near Calvinia. (×1, B. Oelofsen, field collection number USS 1/7/4.)


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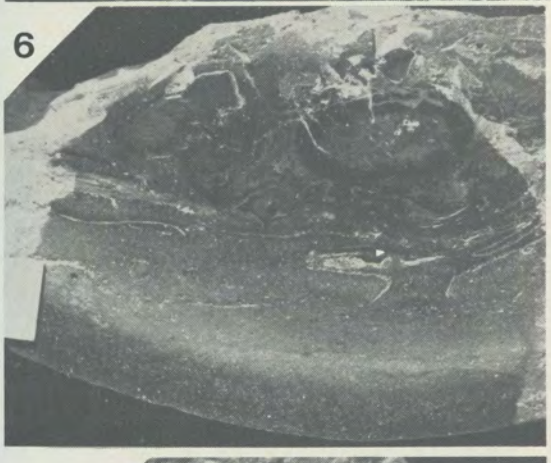
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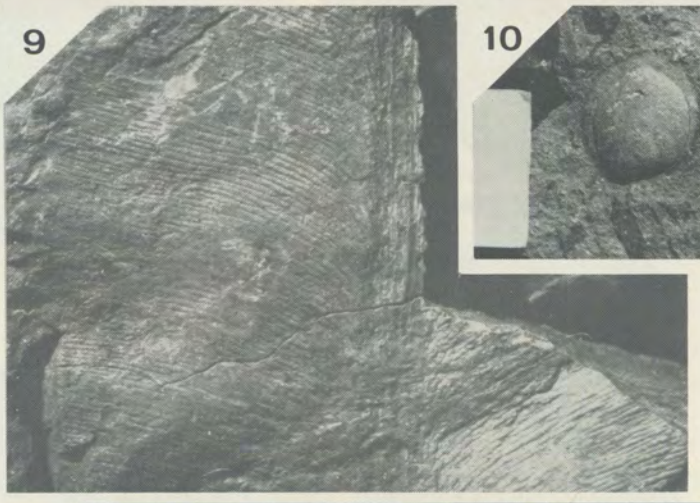
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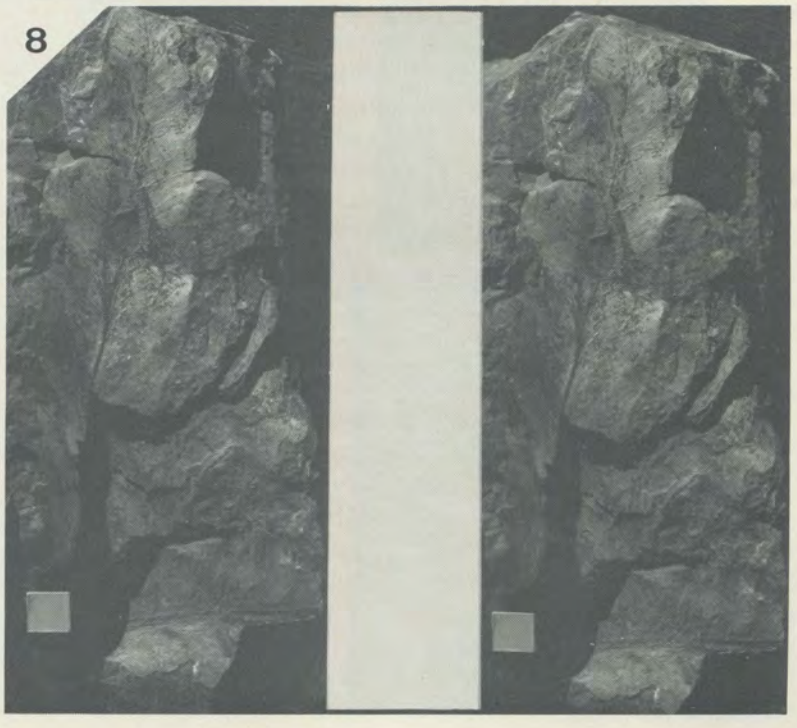
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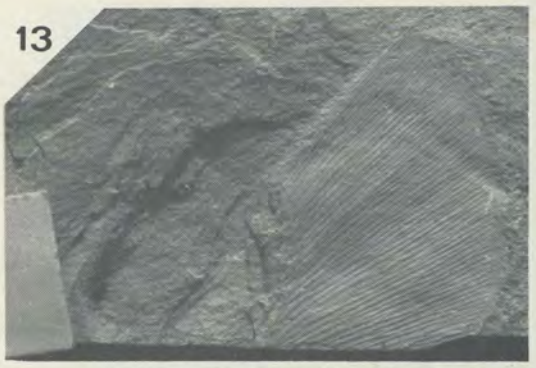

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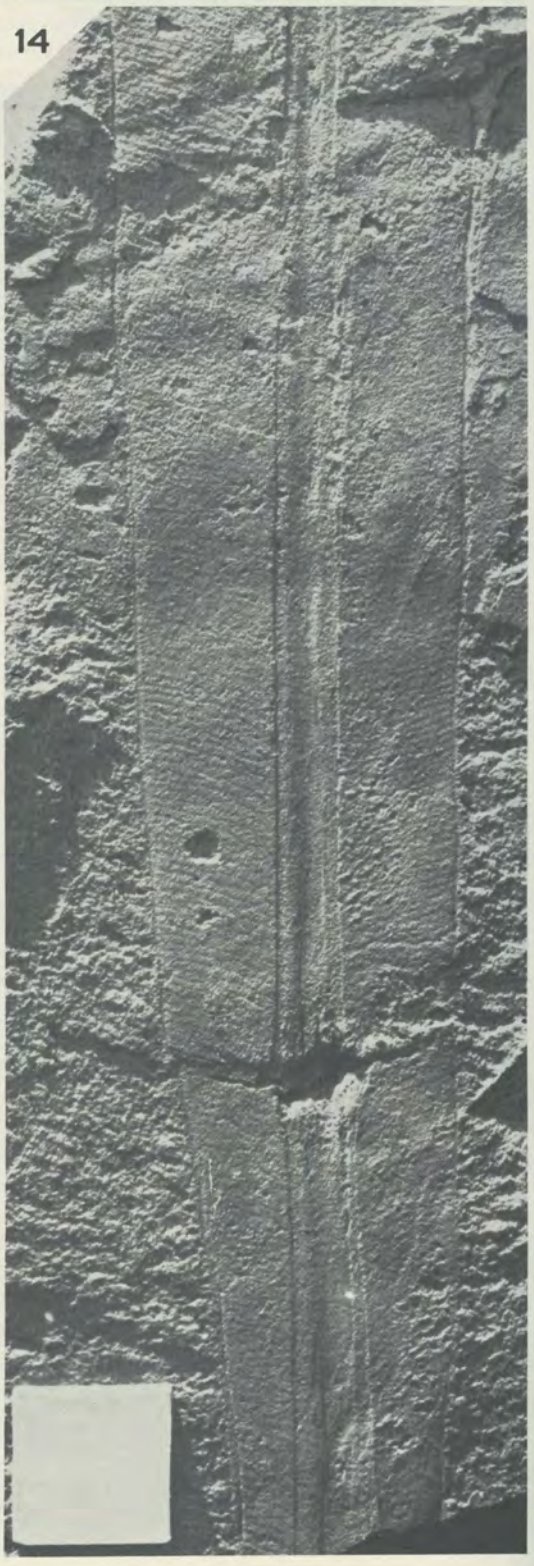

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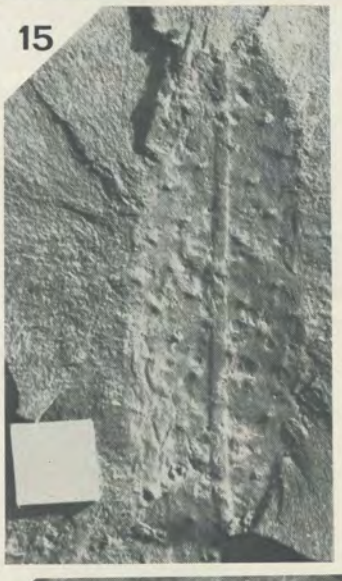

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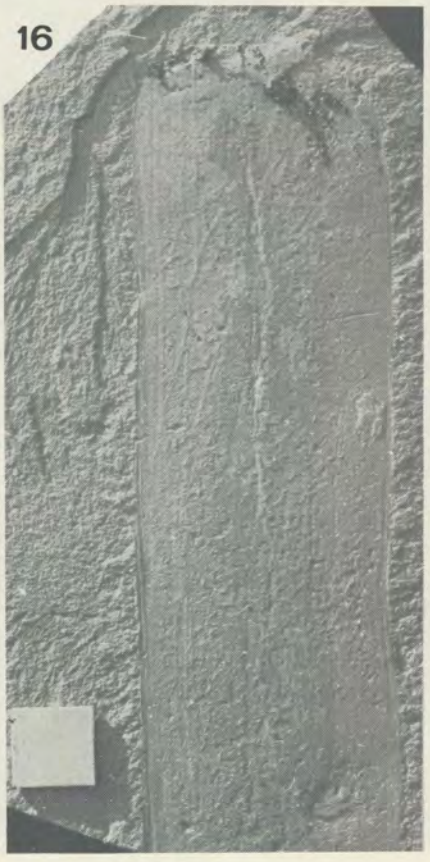

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