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CARBONIFEROUS PYCNOXYLIC WOODS FROM THE DWYKA GROUP OF SOUTHERN NAMIBIA

by

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ABSTRACT

Glacial deposits of the Dwyka Group between Keetmanshoop and Mariental in southern Namibia have been reinvestigated for palaeontological remains and associated tuff horizons in an attempt to accurately date the deposits. SHRIMP-based dating of juvenile zircons from these tuff horizons provide ages which cumulate in the latest Carboniferous (Gzelian). The pycnoxylic woods *Megaporoxylon scherzi* Kräusel and *Megaporoxylon kaokense* Kräusel are described in detail for the first time and are compared with similar permineralised woods from Gondwana. Based on previous fossil wood studies covering the rocks of the main Karoo Basin, these species occur only in the Dwyka and lower Ecca Groups in southern Africa and do not extend to the upper Ecca Group.

KEYWORDS: Dwyka, fossil wood, *Megaporoxylon*, Namibia

INTRODUCTION

Geological setting and general stratigraphy of the Dwyka Group

During the Carboniferous most of the southern part of Gondwana was glaciated. In the Late Carboniferous and Early Permian glaciers receded, depositing the glaciogenic sediments of the Dwyka Group (Karoo Supergroup). In southern Namibia sections of the Carboniferous, glaciogenic Dwyka Group of the Aranos Basin have been subdivided into four deglaciation sequences (DS I-IV, Bangert *et al.*, in press), which were initially recognised by Theron & Blignault (1975) and Visser (1997) in the Western Cape Province, South Africa. In southern Namibia DS I and II began with tillites and debris-rainout diamictites which are overlain by minor siltstones, sandstones and conglomerates representing sediment-gravity flow deposits and fluvio-glacial outwash. The tops of the sequences are formed by lacustrine or offshore marine shale units which are essentially dropstone-free. Of particular importance is an offshore marine mudstone-unit, up to 45 m thick, named the Ganigobis Shale Member (Martin & Wilczewski 1970), which represents the top of DS II and which is especially well exposed in the area between Tses and Ganigobis (Figure 1). This shale member contains well preserved pieces and trunks of permineralised wood some of which are described in this contribution, ashfall tuffs (Bangert *et al.* 1999, Stollhofen *et al.* 2000), concretionary nodules bearing remains of paleoniscoid fishes (Gürich 1923, Gardiner 1962, Bangert *et al.* in press) and spiral coprolites (McLachlan & Anderson, 1973, Bangert *et al.* in press), bivalves (Bangert *et al.* in press), gastropods (Dickins 1961), *Conularia* sp. (Schroeder 1908), sponge spicules and crinoid columns (Bangert *et al.* in press), as well as microbial bioherms (Grill 1997).

Juvenile, magmatic zircon grains were separated from ashfall tuff horizons of the Ganigobis Shale Member and provided $^{206}Pb/^{238}U$ ages of 302.0±3.0 Ma and 299.5±3 Ma (Bangert *et al.* 1999). Within the framework of available numerical time-scales the Ganigobis Shale Member relates to the Late Carboniferous and more specifically to the Kasimovian (cf. Harland *et al.* 1990) or Gzelian (Menning 1995).

Deglaciation sequence III comprises mainly proglacial tunnel mouth and debris rain-out diamictites and gravity flow sandstones which terminate with the 75 m thick Hardap Shale Member (SACS 1980). The latter is characterised by occurrences of the marine bivalve *Eurydesma mytiloides* (Heath 1972), Bryozoa and Asteroidea (Martin & Wilczewski 1970), and has been related to the Gondwana-wide *Eurydesma*-transgression (Dickins 1984). The fourth deglaciation sequence, DS IV, begins with gravity flow sandstones and dropstone-bearing mudstones which are capped by greenish, dropstone-free mudstones immediately below the base of the Ecca Group.

Lithology and fossil content of the fossil wood sites

The fragment of permineralised wood (BP/16/935) described here was found at the Brukkaros River about 400 km S of Windhoek and about 23 km NNW of Tses (No. 1 in Figure 1). The outcrop is located downstream along the Brukkaros River about 2 km SW of the bridge of the B1 road which crosses the Brukkaros River (Figure 1). Stratigraphically the outcrop lies within the upper part of the Ganigobis Shale Member (DS II, Dwyka Group). The up to 5 m high outcrops of the river cuttings have exposed black massive mudstones with interbedded sandy and calcareous horizons which are intruded by five carbonatite dykes. Abruptly lenticular

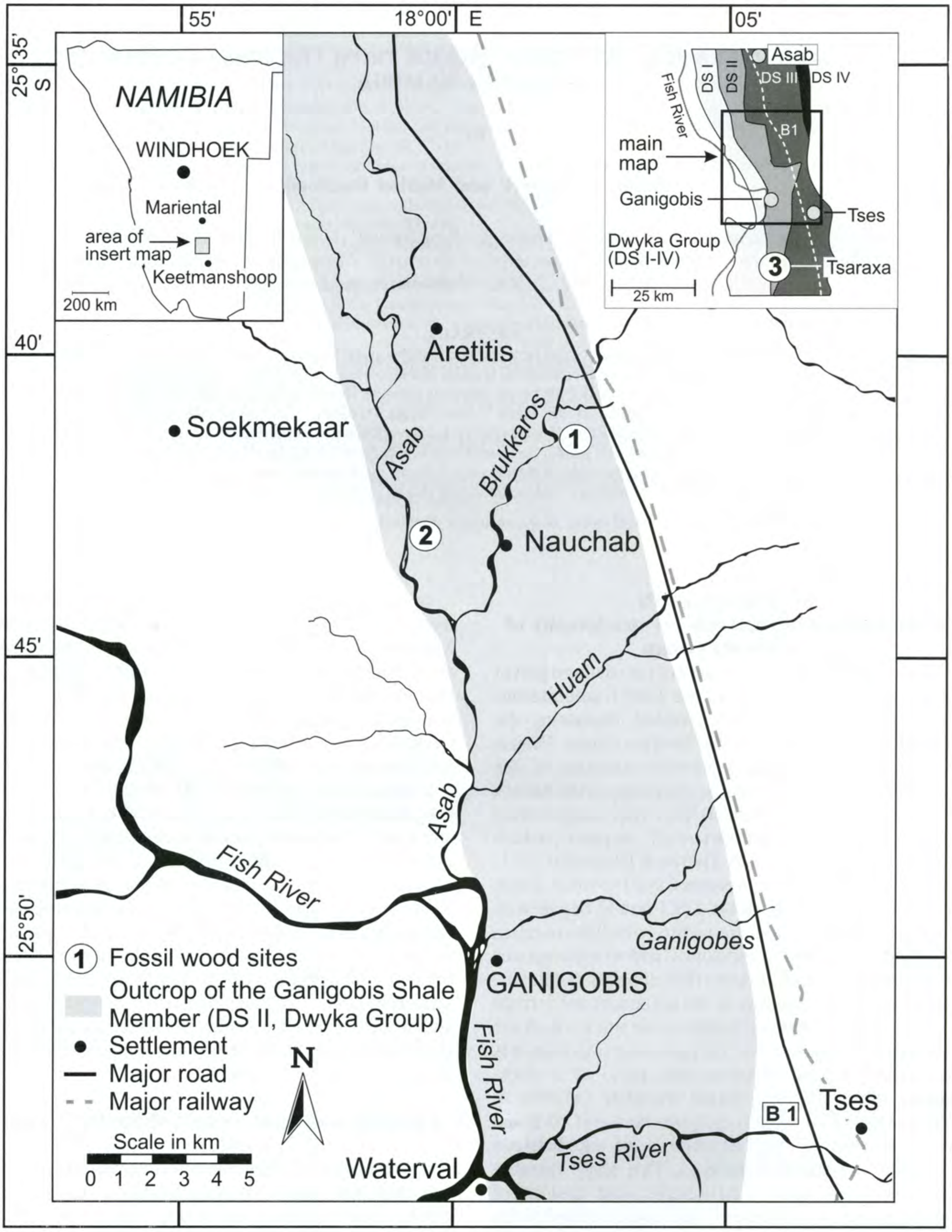


Figure 1. Detailed location map of the type area of the Ganigobis Shale Member in the vicinity of Ganigobis and Tses, southern Namibia, showing the location of the described outcrops.

calcareous sandstone bodies up to 3 m long and 60cm thick are commonly exposed along the river cuttings. A bentonitic tuff horizon is exposed at the top of the river cuttings of the Brukkaros River (VIIIa, cf. Bangert *et al.* in press). The outcrop extends from the river cuttings (25°41.24' S, 18°01.54' E) to a few tens of metres to the east (25°41.26' S, 18° 01.88' E) where flat mounds of nodular siltstones which have diameters of 4-5 m, heights of up to 1.5 m, are exposed. The mounds are covered by round to elongate nodules of brownish-grey massive micrite, which probably represent microbial bioherms (cf. Bangert *et al.* in press).

The following fossils and ichnofossils were detected within the outcrop (cf. Bangert *et al.* in press):

- a single example of *Conularia* sp. (cf. Schroeder 1908),
- numerous shells of *Peruvispira vipersdorfensis* Dickins (1961),
- disrupted boundstone samples with column ossicles of crinoids and small sponge spicules,
- spiral and anvil-like permineralised coprolites (cf. McLachlan & Anderson 1973)
- trace fossils such as *Planolites montanus*, *Planolites* sp. and other indeterminable traces.

Permineralised fossil wood was found *in situ* on the tops of the mounds. The wood was not preserved as complete trunks but as isolated fragments of less than 10 cm in diameter. One especially well preserved sample of completely silicified wood displaying 1-7 mm thick annual growth rings is described in this contribution (BP/16/935, Figures 2-5).

The second described fragment of permineralised wood (BP/16/746) was found at the Asab River about 22 km NW of Tses and 5.5 km SW (25°43.04' S, 17°59.08' E) of the previously described outcrop (No. 2, Figure 1). Stratigraphically, the outcrop lies within the lower part of the Ganigobis Shale Member (DS II, Dwyka Group) which contains abundant concretionary mudstone nodules bearing remains of paleoniscoid fishes and spiral coprolites (cf. Bangert *et al.* in press). The outcrop is also a river cutting which extends a few hundred metres along the western side of the Asab River. The outcrop is dominated by monotonous mudstones sporadically including irregular mudstone concretions (some horizontally aligned) lacking fossils. Four bentonitic tuff horizons occur in the lower part of the outcrop. The described sample of wood was found *in situ* within the lower part of the outcrop.

A third piece of permineralised wood (BP/16/547) was discovered at the Wasser River, near the farm Tsaraxa, about 27.5 km SW of Tses (26°02.55' S, 17°57.20' E, No. 3 in Figure 1). This site is the southernmost outcrop of the lower part of the Ganigobis Shale Member with its characteristic dropstone-free facies changing southwards into shales containing varying amounts of dropstones (cf. Bangert *et al.* in press). Outcrops of the black, massive and dropstone-free mudstones occur in the river cutting of the Wasser River. In this outcrop area three bentonitic tuff horizons were detected, which can be correlated to those located to the north but no other fossils were discovered. The described sample of permineralised wood was collected by Hermann Grill in the outcrop area.

Previously described fossil woods from Namibia

Fossil wood is fairly abundant within deposits of the Karoo Supergroup in Namibia but has seldom been described in detail (Pickford 1995). Descriptions were given by Kräusel (Kräusel & Range 1928, Kräusel 1956a, b), who erected several new genera of pycnoxylic woods with well-preserved primary vasculature and piths. It is the secondary xylem amongst gymnosperm woods that is most frequently preserved. This has led to the development of a dual nomenclatural system. There is a large number of genera for woods with only secondary xylem (woods without a pith = homoxylous, or woods where the pith has simply not been preserved). A separate group of genera incorporates wood with intact primary xylem, pith and secondary xylem (pycnoxylic woods = dense and massive with secondary xylem more abundant, as in tree-like conifers; manoxylic = loose, soft and scanty with the pith more abundant, as in pteridosperms). Pith is generally considered to be the most important feature and woods preserving this tissue are segregated into two groups. Homocellular piths have only parenchymatous tissue whereas heterocellular piths have sclereids, secretory cells, or secretory canals within the parenchymatous tissue. The shape of the pith, cylindrical or variously lobed, is another feature of taxonomic significance.

Lower Gondwanan woods can be divided into five types based on the tracheid pit and spiral thickening arrangements in the secondary wood (Lepekhina1972, Pant & Singh 1987). Thus two specimens with the same secondary xylem but only one having a pith, are placed in different taxa. This is essential because they could belong to different plant groups. Affinities of the woods have been discussed by various authors, but there is little consensus (cf. Kräusel *et al.* 1961, Lepekhina 1972, Pant & Singh 1987). Homoxylous woods have recently been described from the younger formations of the Karoo Basin (Bamford 1999).

The pycnoxylic woods from Namibia and their characteristics are summarised in Table 1. Table 2 shows a comparison of *Megaporoxylon*-type woods described in the literature. In this paper a newly discovered specimen of *Megaporoxylon scherzi* is described because it is particularly well preserved and well dated. Two less well preserved specimens of *Megaporoxylon kaokense* are also described. Polished thin sections were made of all of the silicified woods in the following orientations: transverse section, radial longitudinal section and tangential longitudinal section. The sections were mounted on petrographic slides, ground and polished to a thickness of approximately 25-30 μm, studied and photographed under a Zeiss Axioskop microscope.

DESCRIPTION OF WOOD

Megaporoxylon scherzi Kräusel 1956b.

Specimen No: BB27 and Slide No: BP/16/935
Locality: Brukkaros River, about 23 km NNW of Tses, 25°41.26' S, 18°01.88'E (No. 1: Figure 1)
Stratigraphy: Ganigobis Shale Member, DS II, Dwyka Group, Karoo Supergroup
Collector: Berthold Bangert
Figures: 2-8

Description

The wood is silicified, yellow and brown, and measures 9x5x6 cm. The pith is only a few centimetres in diameter and heterocellular with cells containing a dark substance (secretory cells?) scattered within the parenchymatous pith. The primary xylem lobes are very small and endarch (Figures 2, 3). In longitudinal section the protoxylem tracheids exhibit typical annular or helical thickening (Figure 4). The growth rings are very clearly seen, varying in width from 1-7 mm, with an average of 4,6 mm (Figure 5). Latewood comprises one tenth to one quarter of each ring and ends abruptly at the beginning of the earlywood. The transition from earlywood to latewood is gradual. There are usually 20-30 rows of latewood cells. In transverse section the tracheids of the secondary xylem are square to polygonal and thin walled (wall between two adjacent cells is 5μm wide) in the earlywood, and only slightly thicker in the latewood (7,5μm). The earlywood mean tangential diameter is 35μm (range 25-42 μm) and mean radial diameter is 36μm (range 25-47μm). The latewood mean tangential diameter is 29μm (range 25-35μm) and mean radial diameter is 12μm (range 7-22μm). Bordered pitting on the radial walls of the tracheids is araucarian, predominantly uniseriate and contiguous (90%), slightly flattened, but also biseriate and alternate, and rarely uniseriate and separate (Figure 6). In the earlywood the mean diameter of the pits is 12,5μm, and 10μm in the latewood. The pit apertures are mostly 5μm wide and round but some areas show the cross-like structure of elongated pits of adjacent cells overlapping at right angles, particularly in the narrow latewood tracheids (Figure 7).

The rays are uniseriate and low, 2-10-15 (minimum, mean, maximum) cells high, with thin, unpitted walls. The cross-field pits are oopores: large, simple, oval to fusiform and obliquely orientated, the single pit (very rarely two) filling most of the field (Figure 8). In the earlywood they are on average 37 μm long and 15 μm wide, orientated in the same direction. The latewood cross-field pits are orientated in the opposite direction and are smaller, but because the field is also smaller, they occupy most of the field. These pits are 20 μm long and 5 μm wide, and also without a border. No resin canals, resin or axial parenchyma were seen within the secondary xylem.

Identification

This wood is the same as *Megaporoxylon scherzi* described by Kräusel (1956b) from the upper Dwyka beds (now considered to be the Lower Ecca Group) of the Karoo Supergroup near Mariental. He did not give measurements of the cells or pits but said that the cross-field pits of *M. kaokense* were up to three times as high as the tracheid pits. In *M. scherzi* (Kräusel 1956b) the cross-field pits were very similar to those of *M. kaokense* (Kräusel 1956a) but were oval and slanting, not round. *M. zellei* has slightly shorter oopores (Kräusel 1956b).

Megaporoxylon kaokense Kräusel 1956a

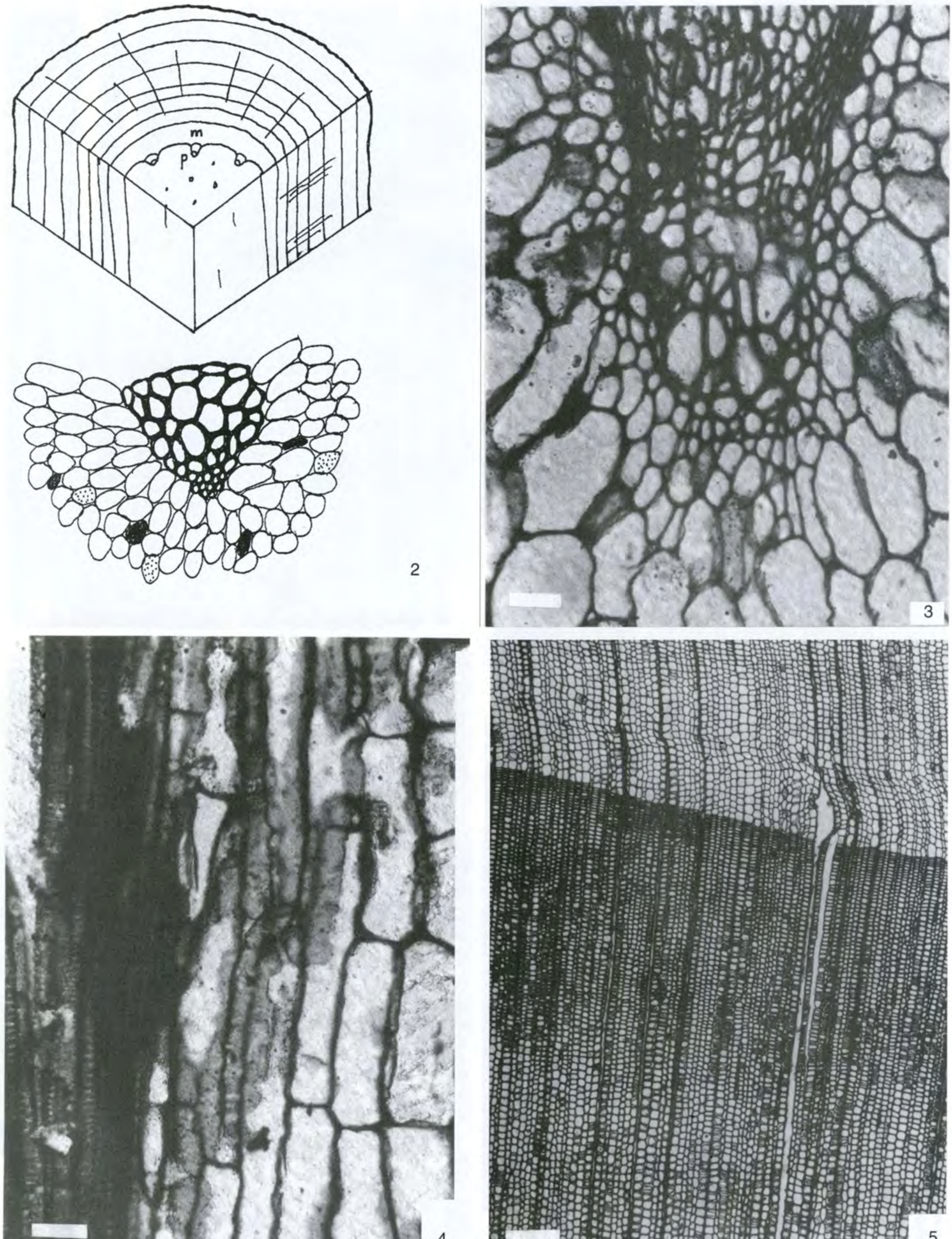
(1) Specimen No: BB28, and slide No: BP/16/746
Locality: Asab River, about 22 km NW of Tses, 25°43.04' S, 17°59.08' E (No. 2: Figure 1)
Stratigraphy: Ganigobis Shale Member, DS II, Dwyka Group, Karoo Supergroup
Collector: Berthold Bangert
Figures: 9-12

Description

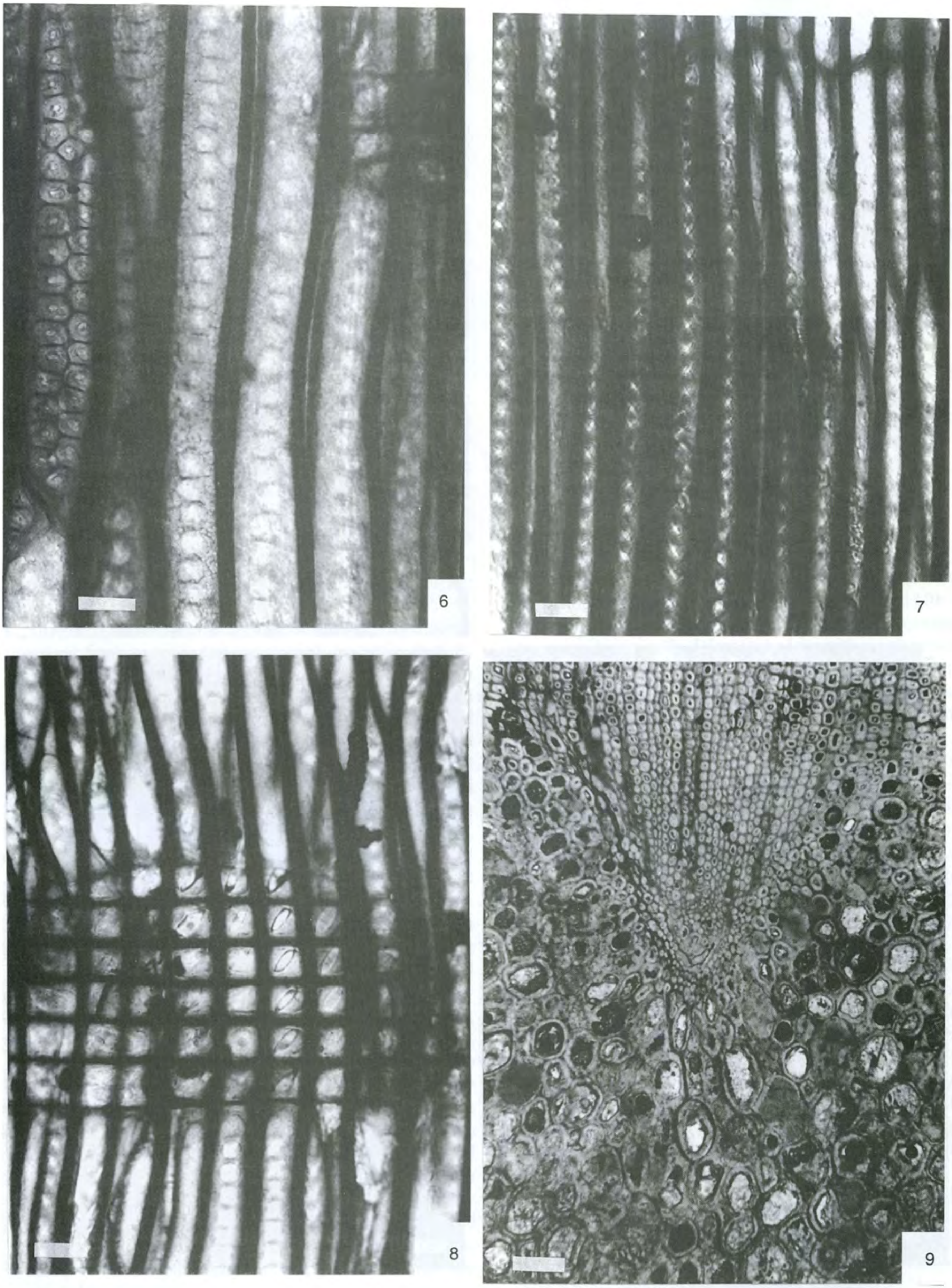
The specimen BP/16/746 is grey, laterally compressed with longitudinal grooves, but has surprisingly well preserved secondary xylem. The pith is heterocellular with secretory cells scattered between the parenchyma cells. Diameter of the pith is unknown. The primary xylem is in lobes extending into the pith and is endarch (Figure 9). In longitudinal section these protoxylem tracheids have close spiral thickening. The metaxylem tracheids have alternate biseriate pitting.

In the secondary xylem the growth rings are on average 1 mm wide and have less latewood, only 2-3 rows, than the specimen described above (BP/16/935). Tracheids are squarish in transverse section and have a dark substance in the lumina which is likely to be an artefact of preservation (Figure 9). The earlywood tracheid mean tangential diameter is 35 μm (range 25-45μm) and mean radial diameter is 33 μm (range 27-45μm). The growth rings are narrow (<1 mm) near the pith. The latewood is made up of 2-3 rows of radially compressed tracheids. The latewood tracheid mean tangential diameter is 33μm (range 20-40μm) and mean radial diameter is 12 μm (range 10-18μm). Adjacent cell walls are 7-10μm thick. Tracheid bordered pitting is clear in some areas (Figure 11). These pits are uniseriate or biseriate and alternate, contiguous and slightly flattened. Their diameter is 12-15μm. There are approximately equal proportions of uniseriate and biseriate pitting.

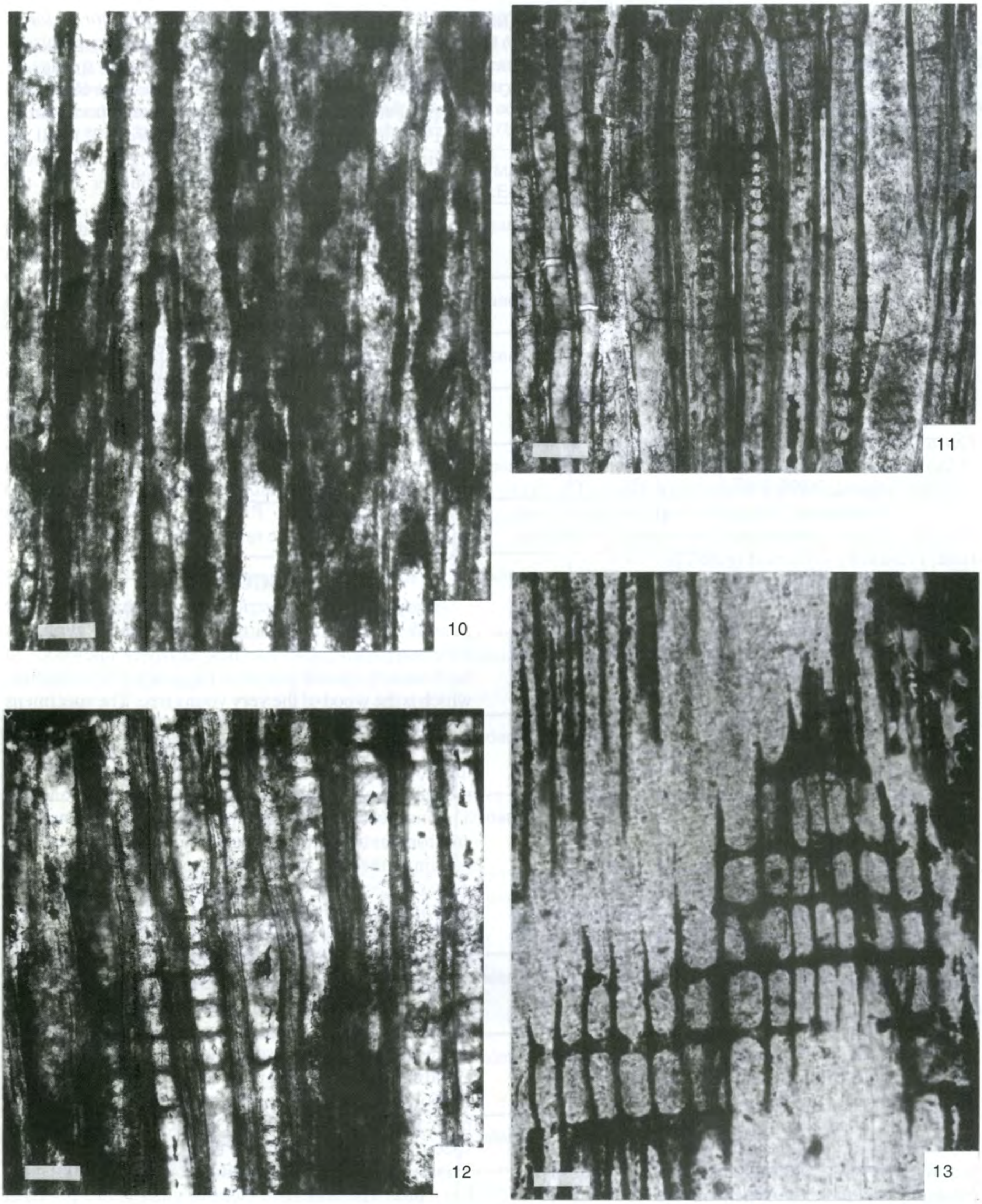
The rays are low, 1-5-12 cells high, exclusively uniseriate and relatively rare (Figure 10). The cross-field pits are large, completely filling the field, simple and almost round, 17.5μm x 17.5μm (Figure 12). No resin or resin canals occur in the secondary xylem.



Figures 2-5. *Megaporoxylon scherzi* Kräusel, BP/16/935; 2: Diagram of specimen showing growth rings in secondary xylem and endarch primary xylem: metaxylem (m, large thick-walled cells), and protoxylem (p, cluster of small thick-walled cells) which is nearer the pith (large thin-walled cells, some with resiniferous contents); 3: Transverse section (TS) of specimen BP/16/935 showing the primary xylem lobe: (secondary xylem above photograph), metaxylem (large central cells), small protoxylem cells just below and large pith cells . Scale bar = 60 µm; 4: Radial longitudinal section (RLS). Protoxylem tracheids have helical and annular thickenings (left), pith cells on the right. Scale bar = 40 µm; 5: (TS). Earlywood tracheids with thin walls in upper part and thicker walled latewood tracheids below. Scale bar = 350 µm.



Figures 6-8: *Megaporoxylon scherzi*, BP/16/935; 6: (RLS). Uni- and biseriate bordered pitting on radial walls of earlywood tracheids. Scale bar = 20 µm; 7: (RLS). Uniseriate pits on radial walls of latewood tracheids. Scale bar = 40 µm; 8: (RLS). Crossfield pitting. Oopores in the earlywood are oval oblique. Scale bar = 40 µm. 9: *Megaporoxylon kaokense* Kräusel BP/16/746. TS showing secondary xylem (top), primary xylem lobe and pith with dark cells below. Scale bar = 175 µm.



Figures 10-13: *Megaporoxylon kaokense* BP/16/746; 10: Tangential longitudinal section (TLS) showing low rays, uniseriate and 3-5 cells high. Scale bar = 40 µm. 11: (RLS). Bordered pits on the radial walls of the tracheids are uniseriate and contiguous. Scale bar = 60 µm. 12: (RLS). Cross-field pits are round oopores, filling the field. Scale bar = 60µm. 13: BP/16/547, *Megaporoxylon kaokense* (Ganigobis Shale Member). (RLS). Cross-field pits are large round oopores, filling the field. Scale = 20 µm.

(2) Specimen and slide number: BP/16/547
Locality: Wasser River, near the farm Tsaraxa, about 27.5 km SW of Tses, 26°02.55' S, 17°57.20' E (Figure 1 insert).
Stratigraphy: Ganigobis Shale Member, DS II, Dwyka Group, Karoo Supergroup
Collector: Hermann Grill
Figure: 13

Description

This specimen is grey-black, measured 9 x 9 x 4,5 cm, has growth rings 1-2 mm wide and was from a trunk with a diameter greater than 50 cm. No pith was preserved, only secondary xylem. The earlywood tracheid mean tangential diameter is 26µm (range 20-30µm) and the radial diameter is 24µm (range 20-30µm). For the latewood the mean tangential diameter is 25µm (range 23-27µm) and mean radial diameter is 13µm (range 10-15µm). Bordered pitting occurs only on the radial walls of the tracheids and is 1-2 seriate, alternate, contiguous or rarely separate, with a diameter of 10µm. The rays are low and uniseriate, 2-5-8 cells high and rare. Cross-field pits are large, simple, round to oval and fill the cross-field, 17.5µm by 17.5µm (Figure 13).

Identification

These specimens are conspecific with woods assigned to *Megaporoxylon kaokense* Kräusel (1956a) from the Tsarabis Formation (Lower Ecca Group, formerly Upper Dwyka) in the southern Kaokoveld. They are very similar to the specimen of *M. scherzi*, described above, except that the cross-field pits are more rounded, rather than elliptic and oblique. Only single pits were seen but there were very few cross-field pits visible altogether.

Comparison with other fossil woods

Kräusel (1956a, b; Kräusel & Range 1928) described 17 taxa of fossil woods from Dwyka and Ecca Group deposits in Namibia which had pith preserved (Table 1). Mostly the piths have small diameters, less than 5 cm, the primary xylem was endarch in the Dwyka woods (one exception), and mesarch in the Ecca woods, and all the secondary woods have araucarian tracheid pitting on the radial walls. Generic differences lie in the pith types and the cross-field pitting. Typical araucarian cross-field pitting is cupressoid (or narrowly bordered), but one specimen, *Dadoxylon arberi*, has small, simple pits of the *Zalesskioxylon* secondary xylem type. The other woods have secondary xylem of the *Protophyllocladoxylon*-type and are shown here in Table 1 as having oopores in the cross-field pit column. In his original description of *Protophyllocladoxylon* Kräusel (1939) described the secondary xylem as having purely araucarian tracheid pitting (slightly compressed pits, usually 2 or more seriate and alternate), but Müller-Stoll & Schultze-Motel (1989) included woods with mixed tracheid pitting (araucarian and abietinian) in this genus. The type of pitting rather than the secondary wood genera are used here to avoid confusion. The secondary xylem of *Megaporoxylon* is the same as that of *Protophyllocladoxylon* Kräusel.

Maheshwari (1966) described a fourth species of *Megaporoxylon, M. krauseli* from the Raniganj (Upper Permian) of India, and two more species from the Permian of Antarctica (Maheshwari 1972). All six species are very similar (Table 2). The species from India and Antarctica are a little younger than the Namibian species. To the best of the authors' knowledge *Megaporoxylon* has not been described from South America but it does occur there (Da Rosa Alves, pers. comm). Kräusel & Dolianiti (1958) described several other genera shared between Brazil and Namibia (*Lobatoxylon*, *Taxopitys*), although different species characterised each area. *Protophyllocladoxylon* is common to both continents (Guerra-Sommer, 1977) but without a pith preserved it is difficult to determine whether the same plant is being considered. The *Protophyllocladoxylon* woods, i.e. those without a pith, occur in the Mesozoic rather than the Palaeozoic (Müller-Stoll & Schultze-Motel 1989), so *Megaporoxylon* and *Protophyllocladoxylon* are unlikely to belong to the same gymnospermous groups.

DISCUSSION

Megaporoxylon scherzi (Figure 5) has very clear growth rings and abundant latewood whereas *Megaporoxylon kaokense* has narrower latewood. In both cases the wood nearest to the pith has been studied, which is the wood of the very young tree. The specimens originate from different localities: *M. scherzi* was found in the upper part and *M. kaokense* was collected from the lower part of the Ganigobis Shale Member and so they are very unlikely to be exactly contemporaneous. The authors cannot assume that their immediate environments were the same, nor do we know for certain if the two species of wood represent different plant taxa because woods tend to be more conservative than other parts or organs of the plant. The growth rings, however, imply a seasonal environment which is to be expected due to the high latitude position of southern Gondwana during the Carboniferous and Early Permian.

The stratigraphically restricted distribution (Carboniferous - Lower Permian) of *Megaporoxylon* makes it a potentially useful biostratigraphic indicator. Gondwanan woods with piths seem to be confined to the Carboniferous and Lower Permian deposits which could be a preservational artefact but of the many intact specimens collected from the Upper Permian and Triassic of southern Africa (Bamford 1999, 2000) none has a pith. The dominant Gondwanan gymnosperms at this time were the Cordaitales, Glossopteridales and early conifers. The Cordaitales have been recorded from the Upper Carboniferous to the Upper Permian deposits with many organ genera having been assigned to this group. The cordaitalean woods *Mesoxylon* and *Cordaioxylon* have large piths with secondary xylem of the *Araucarioxylon*-type (Trivett & Rothwell 1991).The glossopterids are predominantly a Permian group; leaves have also been found in rocks of the

TABLE 1.

Fossil woods described from Namibia by Kräusel (in Kräusel & Range 1928, first eight taxa; Kräusel 1956a,b, the rest of the taxa). All the woods have alternate pitting on the radial tracheid walls of the secondary xylem, variously described as "*Araucarioxylon*-type, *Zalesskioxylon*-type or *Phyllocladoxylon*-type". The main differences are in the cross-field pits which for the three preceding taxa are cupressoid, simple and ooporoid respectively. The Kaoko Formation here is equivalent to the Dwyka and lower Ecca Groups in this region. (Bp = bordered pits on tracheid walls; R = ray width).

FOSSIL WOOD	PITH TYPE	PRIMARY XYLEM	2 XYLEM: CROSS-FIELD	LOCALITY STRATIGRAPHY
Medullopitys sclerotica	heterogeneous sclerenchyma strands	mesarch	oopores	Keetmanshoop Ecca Group
Abietopitys perforata	homogeneous	mesarch	cupressoid	Keetmanhoop Ecca Group
Phyllocladopitys capensis	homogeneous	mesarch	oopores	Ganigobis Dwyka Group
Phyllocladoxylon capense	–	–	oopores	Ganigobis Dwyka Group
Dadoxylon rangei	homogeneous (?)	mesarch	cupressoid	Various Ecca Group
Dadoxylon porosum	homogeneous (?)	mesarch	cupressoid	Keetmanshoop Ecca Group
Dadoxylon arberi	homogeneous (?)	mesarch	simple, small, numerous	Doros crater Tsarabis Fm (Lower Ecca Group)
Taxopitys africana	heterogeneous secretory cells	mesarch	cupressoid spiral thickening	Doros crater Tsarabis Fm (Lower Ecca Group)
Solenoxylon wissi	discoid, large	endarch	cupressoid bp: 1-3	Kaokoveld Tsarabis Fm (Lower Ecca Group)
Solenoxylon kurzi	discoid, large	endarch	cupressoid bp: 1	Kaokoveld Tsarabis Fm (Lower Ecca Group)
Solenoxylon oberholzeri	discoid, large	endarch	cupressoid bp: 2-4; R: 2 ser.	Kaokoveld Tsarabis Fm (Lower Ecca Group)
Lobatoxylon kaokense	lobed	endarch	cupressoid	Kaokoveld Tsarabis Fm (Lower Ecca Group)
Megaporoxylon kaokense	heterogeneous secretory cells	endarch	oopores (round)	Kaokoveld Tsarabis Fm (Lower Ecca Group)
Megaporoxylon scherzi	heterogeneous secretory cells	endarch	oopores (oval, slanting)	Mariental Lower Ecca (?) Group
Megaporoxylon zellei	heterogeneous secretory cells	endarch	oopores shorter	Amalia Dwyka Group
Kaokoxylon reuningi	heterogeneous sclerenchyma	endarch	cupressoid single, small	Kaokoveld Tsarabis Fm (Lower Ecca Group)
Kaokoxylon durum	heterogeneous sclerenchyma	endarch	cupressoid several, smaller	Kaokoveld Tsarabis Fm (Lower Ecca Group)
Phyllocladopitys martini	homogeneous	mesarch	oopores bp: flattened	Mariental Lower Ecca (?) Group

TABLE 2.
Comparison of woods of *Megaporoxylon* described in the literature and in this paper. Growth rings are distinct in all of the species.

SPECIES	LOCALITY STRATIGRAPHY AUTHOR	PITH TYPE Primary xylem	TRACHEID PITS number arrangement size	CROSS-FIELD Number of pits shape size	RAYS width height (cells)
Megaporoxylon kaokense	Kaokoveld, Namibia Tsarabis Fm., Lower Ecca Group Kräusel 1956a	heterogeneous secretory cells endarch	mostly 1 seriate, araucarian --	1 large or 2 smaller, simple, round 3 x size tracheid pits	1 seriate 1-14
M. scherzi	Mariental, Namibia Lower Ecca (?) Group Kräusel 1956b	heterogeneous secretory cells endarch	mostly 1 seriate araucarian	1-2 simple, round to oval and slanting	1 seriate 1-25
M. zellei	Amalia, Namibia Dwyka Group Kräusel 1956b	heterogeneous secretory cells endarch	1-3 seriate araucarian –	1 large, simple, broader and not as high as in *M. kaokense*	1 seriate 1-12-18
M. krauseli	Raniganj, India Upper Permian Maheshwari 1966	heterogeneous secretory cells endarch ?	1-3 seriate	1-2 (-3) large, simple, round	1 seriate 1-6-23
M. antarcticum	Mt Weaver, Antarctica Permian Maheshwari 1972	homogeneous endarch	2-3 seriate araucarian 8-11µm	1 large, simple, elliptical 18 x 11,5µm	1 seriate 2-6-17
M. canalosum	Mercer Ridge Antarctica Permian Maheshwari 1972	heterogeneous secretory cells endarch	1-2 (-3) seriate araucarian –	1 large, simple, oval-elliptic, oblique 16x22 - 5x12µm	1 seriate 1-4-8
BP/16/935 *M. scherzi*	Brukkaros, Namibia Ganigobis Shale Member Dwyka Group Bangert & Bamford	heterogeneous secretory cells endarch	1 (-2) seriate araucarian 10-12,5µm	1 large or 2 smaller, simple, oval and oblique pits 20 x 5 - 37x15 µm	1 seriate 2-10-15
BP/16/746 *M. kaokense*	Ganigobis, Namibia Ganigobis Shale Member Dwyka Group Bangert & Bamford	heterogeneous secretory cells endarch	1-2 seriate araucarian 12-15µm	1 large, round, simple pit, 17,5 µm completely fills the field	1 seriate 1-5-12
BP/16/547 *M. kaokense ?*	near Tses. Namibia Ganigobis Shale Member Dwyka Group Bangert & Bamford	unknown	1-2 seriate araucarian 10µm	1 large, round simple pit, 30 x 25µm, completely fills the field	1 seriate 2-5-8

Dwyka Group in the south-western main Karoo Basin (Anderson & McLachlan 1976). *Araucarioxylon* has been considered the wood type of the glossopterids (Gould & Delevoryas 1977; Pigg & Taylor 1993) but this wood type may have been produced by more than one plant group, especially as this wood type occurs after the extinction of the *Glossopteris* flora. The lack of phylogenetically informative characters currently prohibits assignment of *Megaporoxylon* woods to any gymnosperm order.

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