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FOSSIL WOOD OF CRETACEOUS AGE FROM THE NAMAQUALAND CONTINENTAL SHELF, SOUTH AFRICA

by

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ABSTRACT

Fossil wood was collected from sediments on the Namaqualand shelf, West Coast, South Africa, between the Orange River mouth and just to the south of Kleinzee. Forty three of these samples are here described. All the woods are gymnospermous and have abietinian tracheid pitting. Nineteen of them are well enough preserved to be identified to species level: *Podocarpoxylon* cf. *umzambense*, *Mesembrioxylon* cf. *stokesii*, *M.* cf. *sahnii*, *M.* cf. *woburnense* and *Protocupressinoxylon* cf. *purbeckensis*. The remainder of the woods have been placed in the artificial genus *Mesembrioxylon* without species names. The woods are probably primitive members of the Podocarpaceae growing during the Lower Cretaceous. They indicate a seasonal climate and inhabited the extensive low-lying coastal regions.

KEY WORDS: Lower Cretaceous, South Africa, Podocarpaceae, Cheirolepidiaceae.

INTRODUCTION

There are only a few indigenous conifers in southern Africa today, mainly restricted to the relict forests in the southern Cape, Knysna and isolated montane regions. These conifers are represented by a few members of *Podocarpus, Juniperus* and *Widdringtonia. Phyllocladus,* a genus with which some of the fossil woods show some similarity, is now restricted to New Zealand and Australia. The fossil record, therefore, indicates a greater diversity of conifers in south-western Africa in its geological past.

In the past there were large coniferous forests of unknown extent and duration along the west coast of Southern Africa. Evidence for this is from the huge collection of fossil logs which has been deposited (either *in situ* or transported) on what is today the Namaqualand continental shelf, West Coast of South Africa. Some of these logs have diameters of more than 1m. The land along the coast is now desert or semi-desert and has experienced several cycles of wet and dry climates during the Tertiary. The age of the present desert has been debated for many years but it is most likely that aridification began in Late Mesozoic times (Ward and Corbett 1990).

Nearly all of the 43 samples of fossil wood examined are podocarpaceous with abietinian tracheid pitting, thin and smooth walled ray parenchyma cells, and where preserved, podocarpoid or phyllocladoid cross-field pits. Gothan (1905) erected two genera for such wood, *Podocarpoxylon* and *Phyllocladoxylon*, the difference between them being the size of the cross-field pits. Seward (1919) claimed that it was impossible to distinguish between the genera and instead formed the artificial genus *Mesembrioxylon* which denies any generic affinity. Krausel (1949) favoured Gothan's genera and further clarified the differences. We have not assigned species names to the samples where the cross-field pits have not been preserved and these woods have been placed in the genus *Mesembrioxylon* because the other characters have been preserved.

There is an interesting first occurrence of wood of the Cheirolepidaceae, *Protocupressinoxylon* Eckold. Pollen of this family, *Classopollis*, has been recorded from several deposits elsewhere in southern Africa (McLachlan and McMillan 1976, Scott 1976) of Lower Cretaceous age. The foliage of this family, *Brachyphyllum* and *Pagiophyllum*, has been found in one of the deposits (Kirkwood formation, Algoa Basin; Seward 1903, Bamford 1986). Not all examples of *Brachyphyllum* and *Pagiophyllum*, however, belong to the family Cheirolepidiaceae.

LOCALITY AND GEOLOGY

The specimens of fossil wood described in this paper have been recovered from the continental shelf between the mouth of the Orange River and Kleinzee. The wood was collected in water depths of between 100mbsl. to 150mbsl. during exploration of the shelf by De Beers Marine (Pty) Ltd (Figure 1). The majority of the fossil wood specimens are angular blocks which show minimal evidence of transport. Large logs (diameters of 600 mm), with thin phosphatic rinds coating their surfaces, have occasionally been brought to surface when caught on the anchors of exploration vessels. It is probable that the fossil wood specimens are fragments broken off large trunks by the equipment used to sample the sands and gravels on the shelf for diamonds, and it is likely that even larger fossil tree trunks are present on the shelf.

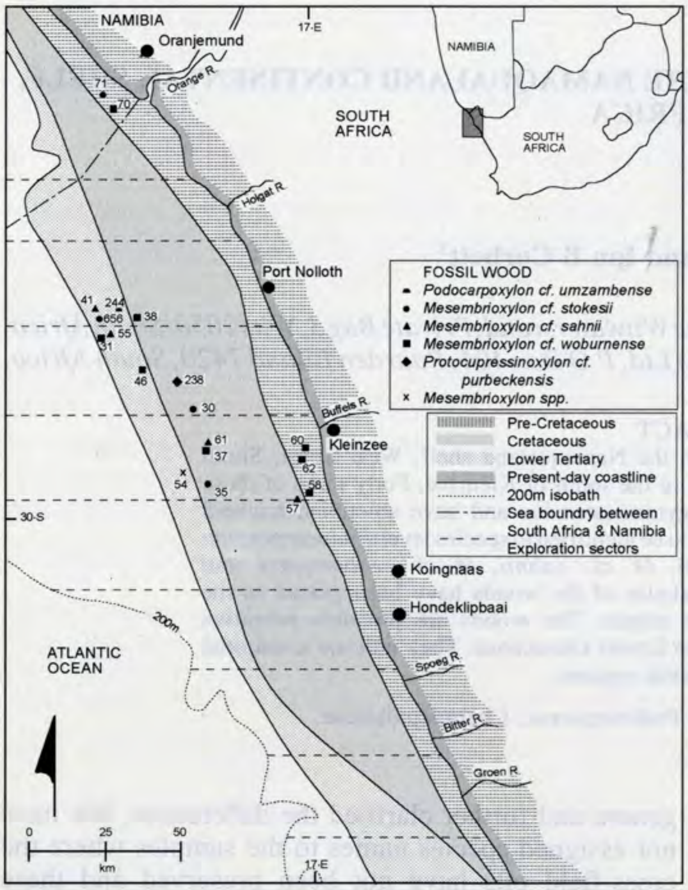


Figure 1. Locality map showing offshore deposits of fossil wood.

Vibracores which provide sections through the shelf sequence show that sub-rounded fossil wood fragments have been incorporated into shelly sand and gravel lags which were deposited during transgression of the Namaqualand shelf by a palaeoshoreline which developed during the Last Glacial between 24kyr. BP. to 12 kyr. BP. (oxygen isotope stage 2).

MATERIALS AND METHODS

Polished thin sections were made in the usual fashion but the thickness of each sample varied (between 25-120μm) depending on the preservation of the wood, and this had to be judged frequently under the microscope during grinding. Sections were made in three planes, transverse, tangential longitudinal and radial longitudinal. The slides were studied and photographed under a petrographic microscope.

DESCRIPTION OF MATERIAL

Podocarpoxylon cf. *umzambense* Schultze-Motel 1966.

BPI Number: BP/16/244
Locality: Namaqualand shelf.
Figures: 2-5.

Description

Growth rings are indistinct and appear as areas of cellular breakdown, 5-7mm apart.

The tracheids are regularly arranged, squarish in outline, and rays are prominent (Figure 2). The early wood tracheids have a mean tangential diameter of 48μm (range 40-59μm) and mean radial diameter of 47μm (range 40-59μm). The late wood tracheids have been crushed. The bordered tracheid pits are uniseriate, mostly separate but occasionally contiguous, and have a diameter of 19μm (Figure 3). They occur on the radial walls only.

Axial parenchyma was not seen but the preservation is poor. Rays are uniseriate with low biseriate portions of 1-4 cells, with an average ray height of 11 cells and range of 3-20 cells (Figure 4). The ray cell walls are thin and smooth. The cross-field pits are single, round, simple and 12-13μm in size (Figure 5). Very little resin is present and there are no ray tracheids or resin canals present.

Identification

This wood belongs to the genus *Podocarpoxylon* because it has small podocarpoid cross-field pits, thin and smooth ray cell walls and abietinian tracheid pitting.

Comparison

This wood is very similar to *Mesembrioxylon gothani* (Stopes 1915: *Phyllocladoxylon gothani*; Seward 1919: *M. gothani*; Thayn and Tidwell 1984: *M. gothani*). The original wood described by Stopes (1915) came from the Aptian deposits on the Isle of Wight. It has low rays (1-8 cells high, average 3), tracheid pits 15-17μm in diameter on the radial walls and elliptical cross-field pits of 7μm diameter.

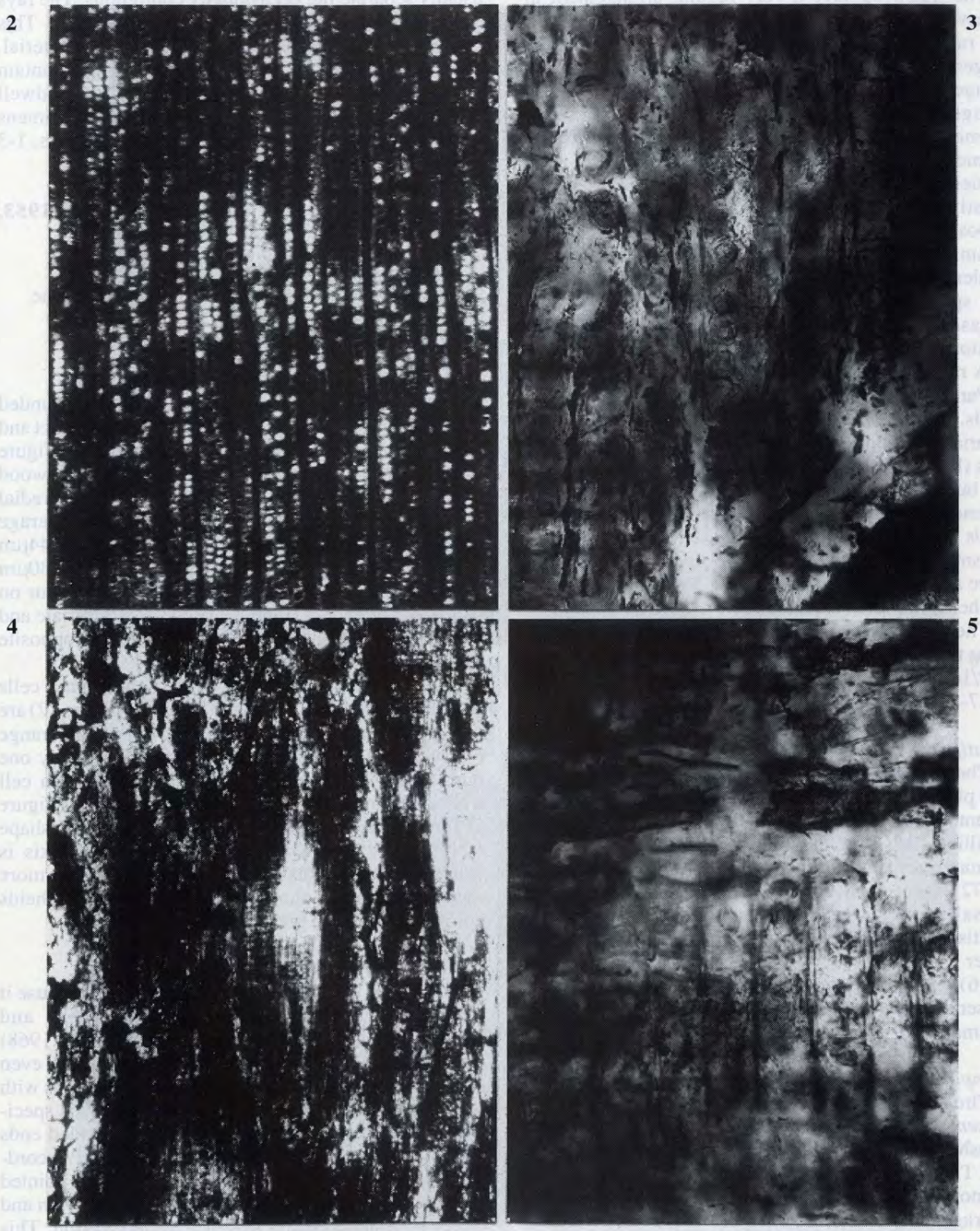
The wood with which this sample compares most closely is *Podocarpoxylon umzambense* (Schultze-Motel 1966) from the Upper Cretaceous of Pondoland, South Africa. This wood has an average tracheid diameter of 13-32μm, uniseriate bordered pits with a diameter of 11-16μm, uniseriate (occasionally biseriate) rays of 1-25 cells high and 1-2 pits per cross-field, 8x5-11x7μm. The Namaqualand shelf material has larger tracheids with larger pits but it is well known that cell sizes vary along the length of the living tree.

Mesembrioxylon cf. *stokesii* Thayn and Tidwell 1984.

Sample: BP/16/35
Locality: Namaqualand Shelf, reworked marine material.
Figures: 6-9
Others: BP/16/30, 65b, 71.

Description

The log is green-grey in colour, 6.5x3x3mm in size (length x radial diameter x tangential diameter) and has narrow growth rings of 1-1.5mm which are fairly regular. Under the microscope the late wood is only a few cells wide. Gum or resin deposits are numerous and randomly distributed.



Figures 2-5. *Podocarpoxylon* cf. *umzambense*, BP/16/244. **2.** TS. Very regular tracheids and prominent rays. Magn 30x. **3.** RLS. Tracheid pits rare but uniseriate and separate. Magn 270x. **4.** TLS. Poorly preserved rays of medium height. Magn 270x. **5.** RLS. Cross-field pits simple, ray walls thin and smooth. Magn 360x.

The tracheids have a very regular arrangement in transverse section, square to polygonal in outline, and the rays are not prominent (Figure 6). The average tangential diameter of the early wood tracheids is 49µm (range 34-60µm), average radial diameter of 48µm (range 40-59µm), and the late wood tangential diameter is 56µm (range 46-64µm), and radial diameter 23µm (range 17-32µm), (Figure 7). The bordered pitting on the radial walls of the tracheids is mostly uniseriate and occasionally biseriate and opposite (Figure 9), and the diameter of the pits is 16-19µm. The bordered pits are preserved as dark, solid circles and no apertures are visible. No bars of Sanio nor spiral thickenings were observed but there are occasional septa in the tracheids. In longitudinal section many of the tracheid and parenchyma cells have dark resinous contents.

Parenchyma is sparse and scattered, with smooth walls. The rays are uniseriate, high and often have two biseriate portions of around 10 cells at the ends of the rays (Figure 8). The average number of cells in a ray is 30 but they range from 2-47 cells high. The ray parenchyma cell walls are thin and smooth and end walls vertical to slightly oblique. The cross-field pits are small, simple with an average diameter of 8µm and there are 1-3 pits per field (Figure 5). There are no ray tracheids nor resin canals.

The three other woods placed in this species have the same tracheid and cross-field pitting and very high rays (BP/16/30, 11-45 cells; BP/16/65b, 7-55 cells; BP/16/71, 7-53 cells).

Identification

The abietinian tracheid pitting and simple cross-field pits place this specimen within the Podocarpaceae. In extant woods only a few species have very high rays (Phillips 1941) and they are rare in the fossil record. Ramanujam and Stewart (1969) and Ramanujam (1972) mentioned several fossil species but these ususally have biseriate to multiseriate rays. The multiseriate condition could be caused by damage or other traumatic conditions (Phillips 1941, Peirce 1936). The Namaqualand woods have very high uniseriate rays and these were unlikely to have been of traumatic origin.

Comparison

The wood shows some similarities with *Mesembrioxylon tiruvakkeraianum* (Ramanujam 1953, Agashe 1968) and *Mesembrioxylon stokesii* (Thayn and Tidwell 1984). *M. tiruvakkeraianum* has sparse, resinous parenchyma, uniseriate, high rays (3-50 cells, average 18) and the cross-field pits are larger, 15-20µm. The tracheid bordered pits are 10µm in diameter, which are smaller than the Namaqualand specimen, and also occur on the tangential walls.

Mesembrioxylon stokesii has septate tracheids and these are also present in BP/16/35 and BP/16/71 but not as numerous. *M. stokesii* also has uniseriate, bordered pitting on the radial walls of the tracheids and they are usually separate but occasionally contiguous. The rays are on average 8-16 cells high (range 1-50). This species is very similar to the Namaqualand material, and is from the Lower Cretaceous Cedar Mountain formation of Utah and Colorado (Thayn and Tidwell 1984). *M. stokesii* and the Namaqualand specimens differ in that *M. stokesii* has small cross-field pits, 1-3 per field, as well as the larger single pits.

***Mesembrioxylon* cf. *sahnii* Ramanujam 1953, Agashe 1968.**

Sample: BP/16/57
Locality: Namaqualand Shelf, reworked marine
Figures: 10-13
Others: BP/16/41, 45, 61, 66.

Description

The log is 8x4x4cm, black and green and well rounded from transportation. The growth rings are indistinct and there are only a few rows of late wood tracheids (Figure 10). The average tangential diameter of the early wood tracheids is 50µm (range 35-62µm), average radial diameter is 58µm (range 40-71µm). The average tangential diameter of the late wood tracheids is 44µm (range 24-59µm) and average radial diameter is 30µm (range 24-40µm). Bordered pits (24x20µm) occur on the radial walls only (Figure 11) and are uniseriate and contiguous, very occasionally biseriate and opposite and with bars of Sanio.

There are numerous resin-filled parenchyma cells scattered throughout the wood. The rays (Figure 12) are uni- to biseriate and on average 15 cells high (range 3-30). The biseriate portions of the rays are only one third of the height of the ray. Ray parenchyma cell walls are thin and smooth. The cross-field pits (Figure 13) are single, large and simple but are elliptic in shape with pointed ends (i.e. fusiform). The long axis is 18µm and the short axis 11µm. Some pits appear more rounded and have a diameter of 16µm. No ray tracheids nor resin canals are present.

Identification

This wood belongs to the Podocarpaceae because it has the large phyllocladoid cross-field pits and abietinian tracheid pitting. Vogellehner (1967, 1968) distinguished between the cross-field pits to an even greater extent than Gothan (1905): large, oval pits with pointed ends as opposed to rounded ends. This specimen has mostly pointed ends with rare rounded ends and that seems to be an artifact of preservation. According to Vogellehner (1968, p. 140) the fusiform (pointed ends) pits would be placed on in *Phyllocladoxylon* and the oval (rounded ends) pits in *Circoporoxylon*. This wood certainly does not have the very rounded pits of the *Circoporoxylon* species described by Krausel and Jain (1963).

Comparison

The Namaqualand Shelf wood is very similar to *Mesembrioxylon sahnii* (Ramanujam 1953, Agashe

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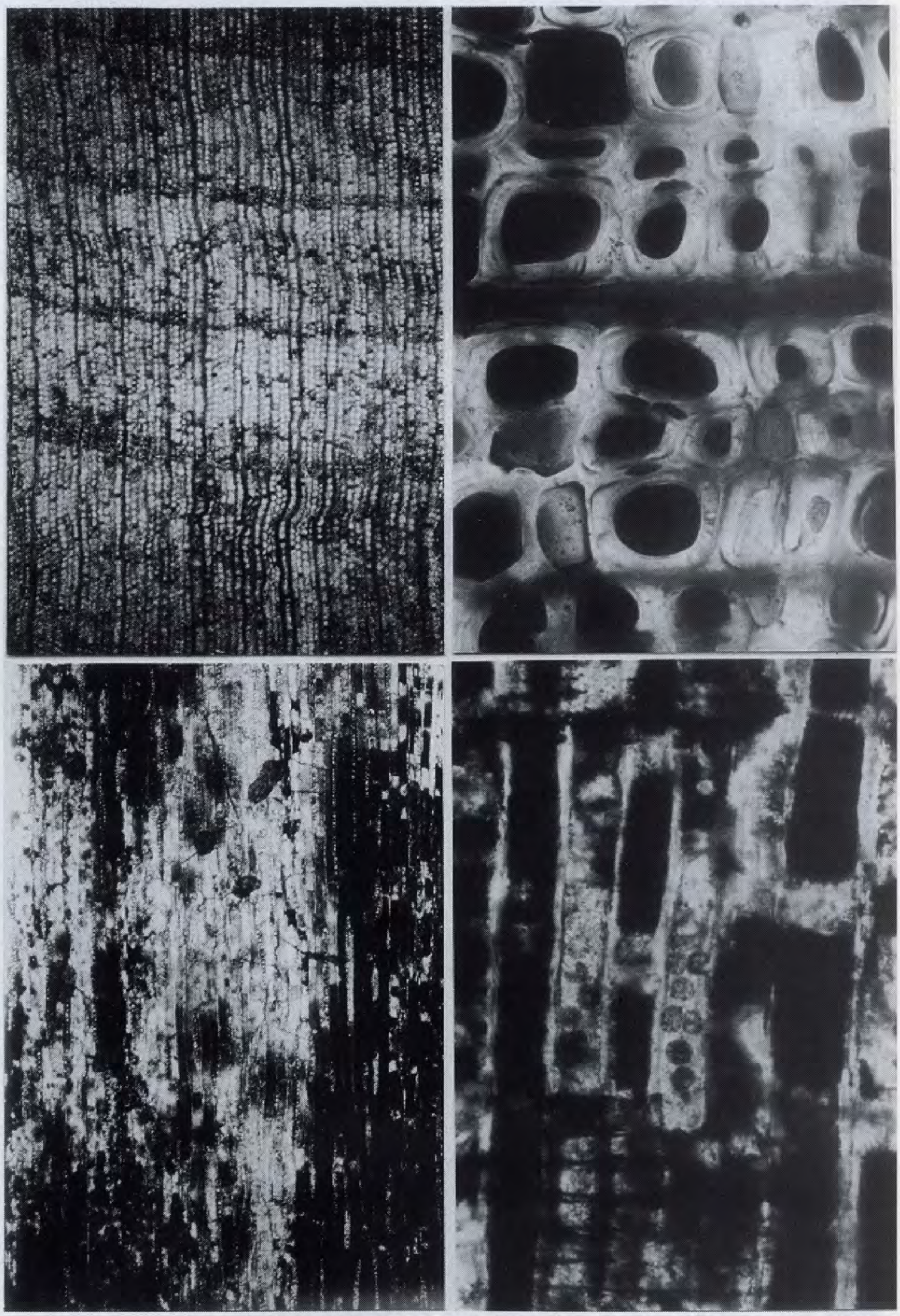
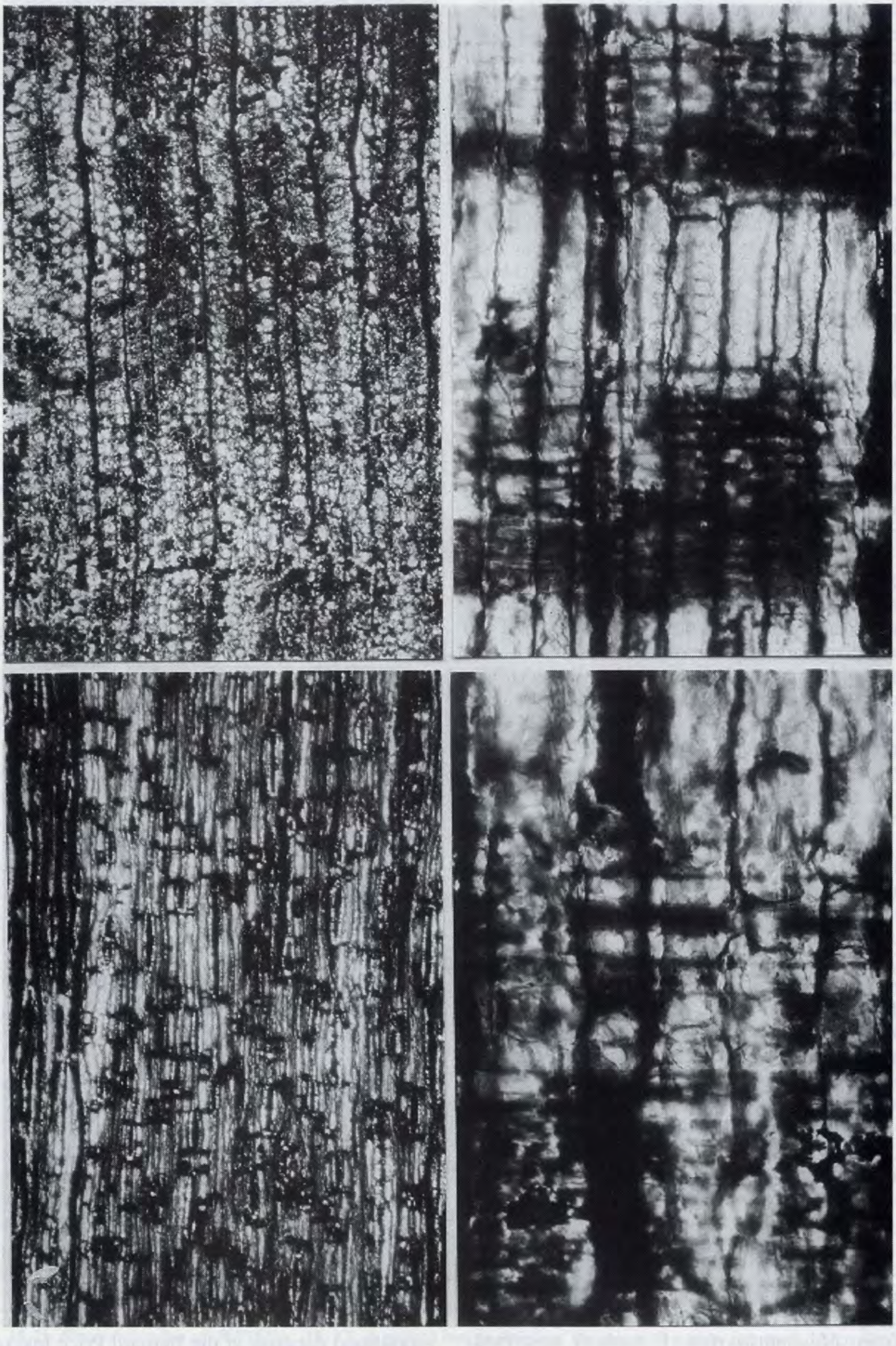


Figures 6-9. *Mesembrioxylon* cf. *stokesii*, BP/16/35. **6.** TS with 4 regularly spaced growth rings. Latewood is narrow and abrupt. Magn 33x. **7.** TS at a higher magnification to show the tracheid walls, resin contents and the bordered pits between adjacent cells. The left side shows earlywood and the right shows latewood radially compressed cells. Magn 420x. **8.** TLS showing high rays (i.e. more than 30 cells), mostly uniseriate but occasionally biseriate. Some tracheids and parenchyma cells have resinous contents. Magn 42x. **9.** Tracheid bordered pits are single or paired and opposite (abietinian). The cross-field pits are small, simple and 1-3 per field. Magn 270x.

10 11 12 13

Figures 10-13. *Mesembrioxylon* cf. *sahnii*, BP/16/57. **10.** TS showing the regular and square tracheids and two growth rings with only 2-3 rows of latewood. Magn 42x. **11.** RLS. Tracheid pitting is uniseriate, and where biseriate the pits are opposite or subopposite and round, i.e. not flattened and alternate as in araucarioid pitting. Magn 270x. **12.** TLS. Rays are mostly uniseriate but some have biseriate portions. The axial parenchyma is resinous. Magn 170x. **13.** RLS. Cross-field pits are simple, oval (fusiform) with the long axis oblique. Magn 420x.



Figures 14-17. *Mesembrioxylon* cf. *woburnense*, BP/16/46. **14.** TS showing prominant rays and faint growth rings at the top and bottom of the photograph. Magn 42x. **15.** RLS showing faint bordered pitting on the tracheids, uniseriate, contiguous and very slightly flattened. Magn 170x. **16.** TLS with uniseriate rays and resin plugs which are the dark, horizontal bands opposite the tops and bottoms of rays. Magn 42x. **17.** RLS. The cross-field pits are large, simple and oblique. Magn 420x.

1968) which has uniseriate, occasionally biseriate and opposite tracheid pits which are contiguous but not flattened. Both woods have the elliptic and oblique cross-field pits with pointed ends. In the Indian wood these pits are much the same size, 15-20mm, and in this wood they are 18x11mm long. The rays of the Indian wood are a bit shorter, 1-20 cells high, mostly 8 cells. The postulated age of the Indian wood is Upper Miocene to Pliocene.

Another wood which has very similar cross-field pits is *Mesembrioxylon fusiforme* Sahni (1920) from the Jurassic or Tertiary of Queensland, Australia. *M. fusiforme* has 1-4 pits per field (no size or magnification is given), and it has low rays (3-5-10 cells).

Mesembrioxylon cf. *woburnense* (Stopes) Seward 1919.

Sample: BP/16/46
Locality: Namaqualand Shelf, reworked marine.
Figures: 14-17.
Others: BP/16/31, 37, 38, 58, 62, 70.

Description

The log is beige and green in colour and 7x2x3cm in size. Growth rings occur as shear or crush zones and so the latewood appears very narrow.

The tracheids are rounded or occasionally squarish and thin walled in transverse section (Figure 14). The average tangential diameter of the early wood tracheids is 59µm (range 48-72µm) and average radial diameter is 63µm (range 51-80µm). The latewood has up to 6 rows of cells and the average tangential diameter is 52µm (range 46-64µm). The average radial diameter of the late wood is 20µm (range 17-27µm). Bordered tracheid pits occur on the radial walls only (Figure 15) and are uniseriate and contiguous and slightly flattened with the line of contact appearing darker. Occasionally the pits are biseriate and opposite. The diameter of the pits is 1µm.

Parenchyma is scattered and resinous. In longitudinal section numerous resin plugs are visible in the tracheids and parenchyma, frequently in line with the top and bottom of each of the rays (Figure 16). The rays are uniseriate and very rarely have low biseriate portions. Whole rays are 9-35 cells high, mostly 15 cells. Ray parenchyma cell walls are thin and smooth. The cross-field pits (Figure 17) are simple, single or paired, round to oval and 18-24µm in diameter. Neither ray tracheids nor resin canals are present.

Identification

The abietinian tracheid pitting and 1-2, large, simple cross-field pits place this wood in the Podocarpaceae. It differs from *Mesembrioxylon* cf. *stokesii* described here, in having much lower rays with less frequent biseriate portions and larger cross-field pits.

Comparison

This wood is most similar to *Mesembrioxylon woburnense* (Stopes 1915: *Podocarpoxylon woburnense*, Seward 1919: *Mesembrioxylon woburnense*) from the Aptian of Bedfordshire, England. The English wood has similar shaped cross-field pits which are 9-15mm in size; the rays are 1-40 cells high, uni- to occasionally biseriate and the tracheid pits are mostly uniseriate, sometimes paired and opposite. Crassulae are reported in the English wood but do not occur in the Namaqualand wood.

Mesembrioxylon sp.

Sample: BP/16/54
Locality: Namaqualand Shelf, reworked marine.
Figures: 18-21
Others: 24 specimens.

Description

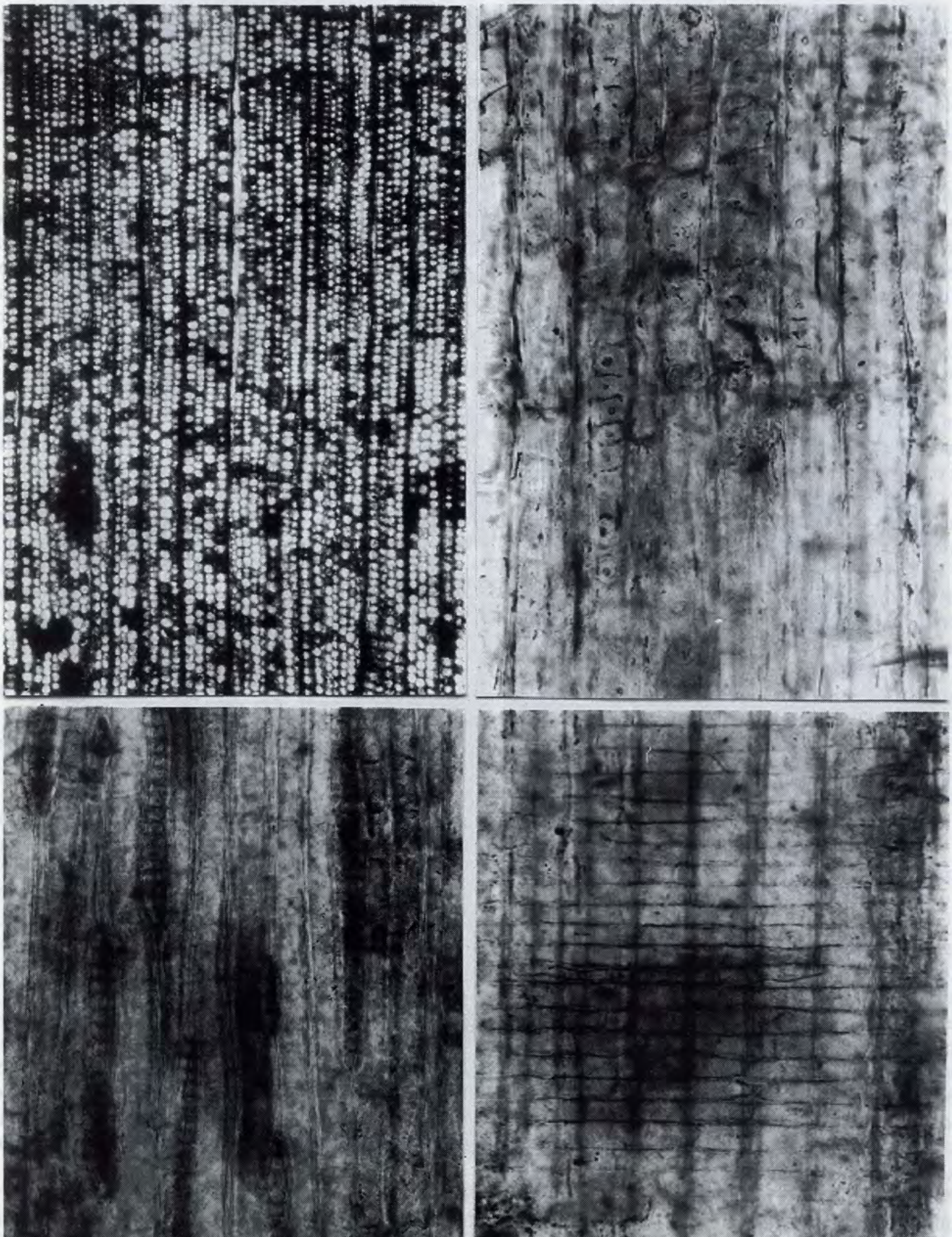
The log is grey and white and is 7x1.5x1.5cm. The growth rings are indistinct and variable, and the tracheids have a very regular distribution in transverse section (Figure 18). They are square to polygonal in outline. The average tangential diameter of the early wood is 53mm (range 40-64mm) and the average radial diameter is 51mm (range 40-62mm). The late wood forms only 2-3 rows and the average tangential diameter of the tracheids is 50mm (range 43-59mm); the average radial diameter is 31mm (range 25-39mm). The radial pits are uniseriate, contiguous and 17-18mm (Figure 19). Resin occurs in the tracheids and the parenchyma.

Parenchyma is sparse but occasionally columns of the horizontal walls are seen in TLS (Figure 20). The rays are uniseriate, with rare biseriate portions of 4-5 cells. Ray height is 5-34 cells with an average of 10 cells. The ray cell walls are thin and unpitted and the endwalls vertical or slightly oblique. Cross-field pits are not preserved (Figure 21). Neither spiral thickening nor resin canals are present.

Identification

All the specimens of wood in this section have the abietinian tracheid pitting and rays of medium height with thin, unpitted walls which belong to the Podocarpaceae, but without preserved cross-field pits they cannot be placed in any species. We have, therefore, placed them in the artificial genus Mesembrioxylon (Seward 1919) which has a variety of cross-field pits depending on the interpretation of author. These specimens may well fit into the species described above, and others too, but the preserved features give no indication of which genus or species. The exception is BP/16/30 which has the very high rays characteristic of *Mesembrioxylon* cf. *stokesii*.

These woods have been added to the recently established database at the Bernard Price Institute for Palaeontological Research, Johannesburg, as even if incompletely identified, their occurrence, is important for the distribution of these wood types.



Figures 18-21. *Mesembrioxylon sp*. BP/16/54. **18.** TS. A growth ring is visible at the top, with narrow latewood. Magn 42x. **19.** RLS. The bordered pits on the tracheids are uniseriate, contiguous and slightly squashed, with small apertures. Magn 270x. **20.** Uniseriate rays with occasional biseriate portions. Magn 170x. **21.** RLS. The ray parenchyma walls are thin and smooth, as in all the other specimens. The end walls are vertical to oblique and also smooth. The cross-field pits are not preserved. Magn 270x.

Cheirolepidiaceae

Protocupressinoxylon cf. *purbeckensis* Francis 1983.

Sample: BP/16/238
Locality: Namaqualand shelf.
Figures: 22-25

Description

The specimen is a small pebble with a 20mm diameter, and was probably a branch. Seven growth rings were preserved of uneven diameter but with an average of 1.3mm.

The tracheids are thin walled and were probably regularly arranged before the slight distortion during preservation (Figure 22). The early wood tracheid tangential diameter has an average of 18µm (range 10-25µm), and average radial diameter of 17µm (range 13-24µm). The latewood is very narrow and squashed with 3-8 rows of cells. The average tangential diameter is 18µm (range 14-24µm) and average radial diameter is 10µm (range 6-16µm) for the late wood tracheids. Wall thickness (two adjacent cells) is 7µm. The tracheid bordered pitting (Figure 23) is on the radial walls only, and is uniseriate, separate or contiguous, never compressed as in araucarian pitting. The diameter of the pits is 13-16µm.

Axial parenchyma is absent. The rays are uniseriate and very low (Figure 24), average number of cells is 2-5, (range 1-6). The ray cell walls are much thinner than the tracheid walls and smooth. The cross-field pits are cupressoid, 2-7 per field and arranged in two horizontal rows. The pit diameter is 6-8µm and the pore oblique and 3µm in diameter (Figure 25).

Identification

The cross-field pits are cupressoid, vertical parenchyma is absent but resiniferous tracheids are present and resin also occurs in the ray cells which are all features of the Cheirolepidiaceae. The only discrepancy is in the tracheid pitting. The members of Cheirolepidiaceae have uni- and biseriate pitting but this specimen is a small branch with relatively narrow tracheids and no biseriate pitting is found. It is most like *Protocupressinoxylon*. This genus has biseriate and opposite tracheid pitting. The Namaqualand wood is also similar to several species of *Cupressinoxylon* except for the absence of parenchyma. Parenchyma and various wall ornamentations, such as pits or nodules, are common features of extant members (Peirce 1937) and fossil members (Vaudois and Prive 1971) of the Cupressaclal.

Comparison

The Namaqualand shelf wood is similar to *Protocupressinoxylon purbeckensis* (Francis 1983) from the Upper Jurassic Lower Purbeck Formation of Dorset, England. *P. purbeckensis* has an average tracheid diameter of 47µm, uniseriate (rarely opposite) bordered pits, diameter 17µm. The rays are uniseriate with an average height of 3 cells (range 2-9), with thin, smooth walls. There are 2-7 small cupressoid pits per cross-field with a diameter of 7-µm and the apertures inclined at 45°. The wood described here has no biseriate pitting and so is called *Protocupressinoxylon* cf. *purbeckensis*.

DISCUSSION

Deposition

The fossil wood specimens show no evidence of degeneration from biotic factors such as bacteria, fungi or boring insects. This suggests that burial of the wood occurred shortly after deposition on the continental margin. In view of the good preservation and age of the fossil wood, initial burial must have occurred during the late Early Cretaceous, when sedimentation rates along the west coast of southern Africa were particularly high (Dingle *et al.* 1983), which resulted in the depositon of a large Cretaceous wedge of sediment as the continental shelf prograded to the west. The silicification of the wood probably also occurred post-depositionally during the Cretaceous. It is not known whether the wood was deposited in close proximity to a Cretaceous palaeoshoreline or not. The examination of the Cretaceous deposits exposed on the continental shelf suggests that the wood is more likely to have been deposited in continental clastic sequences which were probably sand and gravel dominated.

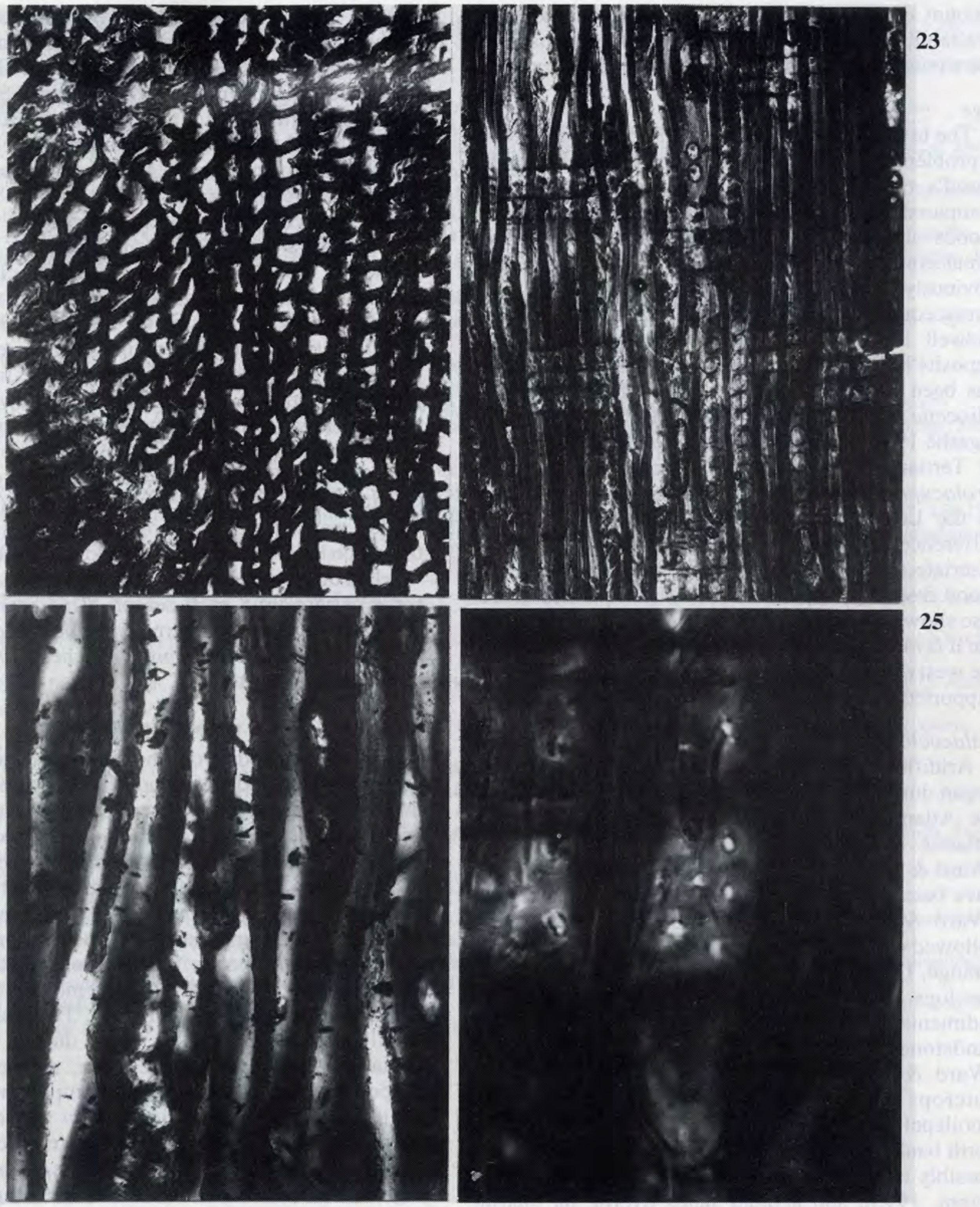
Rapid burial and silicification of the wood probably reduced compression during burial, which was possibly further reduced by burial of the wood in sand-dominated rather than mud-dominated clastic sequences (Ward pers. comm.).

Many of the specimens of fossil wood described in this report have been recovered from the portion of the Namaqualand continental shelf that is floored by Cretaceous sediments (Figure 1) which were overlain by a thin marine Late Pleistocene to Late Holocene sequence. The fossil wood has probably been derived by the erosion of late Early Cretaceous and Late Cretaceous continental clastic sequences on the shelf during later marine transgressions and regressions which have removed and reworked the entire Palaeogene and Neogene section across much of the inner and middle shelf. The last trangressive event resulted in the incorpation of the wood in to the marine Late Pleistocene sequence during the Last Glacial.

Diversity

It is interesting that relatively few wood types represented here occur over such a large area. Forests with a low diversity are fairly common in the fossil record, for example *Protocupressinoxylon purbeckensis* is the dominant conifer in the Jurassic Purbeck formation, England (Francis 1983) and *Araucarioxylon arizonicum* is dominant in the Chinle formation (Upper Triassic) in Arizona (Ash & Creber 1992).

The fossil wood distribution across the continental shelf does not appear to be uniform (Figure 1), however, this is partly due to the method of sampling, together with subsequent changes in the lateral extent



Figures 22-25. *Protocupressinoxylon* cf. *purbeckensis*, BP/16/238. **22.** TS. Rectangular tracheids distorted after preservation. Magn 360x. **23.** RLS. Uniseriate tracheid pitting, not squashed. Magn 270x. **24.** TLS. Low rays. Magn 360x. **25.** RLS. Cupressoid cross-field pits. Magn 1000x.

of the Cretaceous sequences which contain wood, and the extent of erosion which has occurred across the continental shelf. The distribution (Figure 1) is therefore unlikely to reflect the actual distribution of the living wood.

The woods are very similar to each other in structure but the preservation varies considerably, in both the quality and the mineral content, which means that different areas of deposition had different minerals in solution. (Here an "area" could be only metres or kilometres apart).

The homogeniety of the wood, nonetheless, implies that the flora, as far as the trees were concerned, had a low diversity, and probably the coniferous forests covered fairly large areas. The understorey vegetation is unknown and would depend to a large extent on the amount of light reaching the forest floor and water availability. As some of the wood has been transported there is no knowing how dense this conifer "forest" was.

Age

The taxonomic status of the early coniferous woods is problematic and changes frequently. Nonetheless the wood's characters do not. These woods have been compared with both northern and southern hemisphere woods and have been found closest to the Lower Cretaceous woods. *Mesembrioxylon* cf. *stokesii* is obviously comparable with *M. stokesii* of the Lower Cretaceous Cedar Mountain formation (Thayn and Tidwell 1984). *M. woburnense* is from the Aptian deposits in Bedfordshire (Seward 1919). *M.* cf. *sahnii* has been compared with *M. sahnii* from the Upper Miocene to Pliocene of India (Ramanujam 1953, Agashe 1968) and with *M. fusiforme* from the Jurassic or Tertiary of Queensland, Australia (Sahni 1920). *Protocupressinoxylon* cf. *purbeckensis* is very similar to the Lower Jurassic *P. purbeckensis*, the only difference being the tracheid size and the absence of biseriate tracheid pitting in the very small piece of wood from Namaqualand. The Namaqualand woods also show some similarities with Tertiary Indian woods but it is most unlikely that the climate, anywhere along the west coast or inland during the Tertiary, could have supported the growth of these large diameter trees.

Palaeoclimate

Aridification of the west coastal belt most probably began during the Late Mesozoic when the opening of the Atlantic started from the south and the South Atlantic anticyclonic circulation system developed (Ward & Corbett 1990). Also the Namib would then have been on the rainshadow side of the subcontinent (Ward & Corbett 1990). Offshore sedimentation followed during the middle and Late Cretaceous in the Orange, Luderitz and Walvis basins, and this is when the logs may have been washed out to sea. The sediments laid down during the Tertiary, the Tsondab sandstones, were formed under desert conditions (Ward & Corbett 1990). The Tsondab sandstone outcrops are in the central Namib. The Lower Rooilepel sandstone to the east of Oranjemund, on the north bank of the Orange River, is Lower Miocene or possibly older according to Pickford and Senut (pers. comm. 1993), and aeolian sands overlie the marine sequence preserved at Buntfeldschuh in southern Namibia. These are tentatively dated as Late Palaeocene to Early Eocene.

Extant members of the Podocarpaceae occupy mainly tropical montane regions yet the ancestral members occurred in low-lying plains (Duperon-Laudoueneix & Pons 1985). The West Coast "forests" probably also occupied the low-lying plains. The Cheirolepidiaceae from all over the world occupied a variety of climatic regimes but they show evidence of tolerating some drought (Vakhrameev 1970). Francis (1983, 1984) described *Protocupressinoxylon purbeckensis* as a large, shallow-rooted, monopodial tree forming a closed canopy forest alongside a hypersaline lagoon in England. It probably experienced a winter rainfall and arid summer climate. The Namaqualand *P.* cf. *purbeckensis* most probably grew in the low-lying coastal plains and experienced a strongly seasonal climate.

The growth rings which are present in all the specimens vary in width from 0.5mm to 11mm and show that the wood grew in a seasonal climate. The variability has no real meaning in such a widespread collection of wood because the trees could have grown in different areas, at different times and therefore do not indicate any particular local climate. The large size of the trees, over 1m in diameter, and the width of the growth rings, indicate a good growth regime. The growing season is represented by the large amount of earlywood and this may well have been quite rapid because there are frequent shear zones (large, thin walled cells which collapse under pressure). The transition to latewood is abrupt and very little latewood was laid down which means that growth was suspended for a certain time each season. This seems to be a common feature of southern hemisphere trees, whereas the northern hemisphere pines, larches, firs, etc. have large regions of latewood.

CONCLUSION

The fossil woods from the Namaqualand Shelf are predominantly podocarpaceous and have been placed in five taxa. The rest have been lumped into an artificial genus only because the crucial features have not been preserved. These specimens are still podocarpaceous. Modern Podocarpaceae have a distribution restricted to the southern hemisphere, but were much more widespread during Palaeozoic and Mesozoic times. One specimen belongs to the Cheirolepidiaceae, an extinct family of conifers, some members of which could tolerate periods of drought. The Namaqualand fossil trees most probably grew during the Lower Cretaceous, in a seasonal climate, and growth was suspended when water and/or temperature became limiting. Burial and silicification most probably occurred during the mid and Late Cretaceous erosion phase. Subsequent marine transgressions and regressions have resulted in the woods being reworked and incorporated into sediments deposited on Late Pleistocene palaeoshorelines.

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LIST OF ABBREVIATIONS

BP/16/ – Bernard Price Institute, Johannesburg fossil wood collection.

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