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DOCTOR OF PHILOSOPHY

# Studies in Antarctic palaeobotany.

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# STUDIES IN ANTARCTIC PALAEOBOTANY

A THESIS SUBMITTED TO THE UNIVERSITY OF WALES

IN CANDIDATURE FOR THE DEGREE OF

PHILOSOPHIAE DOCTOR.

Roger C. Lucas

[561 (99)]

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"Polar Exploration.......nowhere has knowledge been purchased at greater cost of privation and suffering."

Fridtjof Nansen.

## ABSTRACT

Collections of three fossil floras have been made recently by the British Antarctic Survey.

They include Lower Permian material from the Theron Mountains, Coats Land, Antarctic Mainland, Mid - Upper Triassic material from Livingston Island in the South Shetlands and Tertiary material from King George Island in the South Shetlands.

Each collection is described in detail systematically and is discussed with reference to its composition, comparison with other floras, age and possible palaeoenvironment.

## ACKNOWLEDGEMENTS

Thanks go to the British Antarctic Survey, in particular to Doctor M. R. A. Thomson for providing the material and details of the collection sites; to the staff of the British Museum (Natural History) for permission to study extensive collections for comparison purposes and to the Natural Environment Research Council for financing the 'Studies in Gondwanaland Palaeobotany' project.

I would like to thank especially Professor W. S. Lacey for not only introducing me to the fascinating field of palaeobotany, but also for providing constant advice and encouragement throughout my research career.

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# GENERAL INTRODUCTION:
# MATERIAL AND TECHNIQUES

# GENERAL INTRODUCTION

The myth of 'terra australis' persisted for over two thousand years and it was not until Tasman and Cook had disproved that both Australia and New Zealand were not part of this large land mass, in combination with Cook's circumnavigation of the south pole at approximately 60°S (at one point reaching 71°S) that real progress was made.

Cook's voyage had proved that if any continent existed it could be no larger than Antarctica, for although large islands might still exist somewhere in those southerly latitudes, this careful survey had ruled out the possibility of a major land mass north of the Antarctic circle.

According to records, the first sighting of Antarctica occured in 1820 by Captain William Smith discovering Trinity Land (now known as Graham Land). Antarctica was resighted jointly several months later by Palmer and Bellinghausen who had both circumnavigated the continent in a more southerly latitude than did Cook.

The first landing took place in 1821 by Captain John Davis, and the first fossil ever recorded was a piece of wood from the South Shetland Islands observed during the United States expedition of 1829 - 1831 under the command of B. Pendleton (Thomson, 1977).

Subsequent expeditions by Weddel, Dumont d'Urville (1837 - 1840), Wilkes (1838 - 1842), Ross (1840 - 1843), Larsen, de Gerlach (1897 - 1899) and Borchgrevink (1898 - 1900) all helped to provide an accurate outline and greater knowledge of Antarctica.

At the turn of the century, the furthest south any man had ventured was approximately 78°50′S.

The first major fossil plant collections were made by the Swedish South Polar Expedition (1901 - 1903) in West Antarctica and by the British National Antarctic Expedition (1901 - 1904) in East Antarctica.

The pole was conquered in 1910 by Amundsen and this allowed leaders of later expeditions to concern themselves solely with scientific discovery.

The most notable of these were the British Antarctic Expedition (1910 - 1913), Australian Antarctic Expedition (1911 - 1914), expeditions by Byrd (1929), Wilkins (1928), Ellsworth (1935), British Grahamland Expedition (1934 - 1937), Falkland Islands Dependencies Survey (1948 - 1949), the famous Trans - Antarctic Expedition (1955 - 1958) and the United States Antarctic Expeditions from 1935 to the present day.

In 1971 there were forty - three occupied research stations run by ten nations (Mountfield, 1974), including a station actually at the pole which was first set up during the International Geophysical Year in 1957 by the Americans, but was subsequently rebuilt during the early 1970's (Neider, 1972).

Some of these stations are only occupied during the summer months, but others like the American base at McMurdo Sound have a winter population of two hundred which swells to over a thousand during the summer.

For convenience, Antarctica is divided into east and western halves approximately marked by the great chain of the Trans - Antarctic Mountains.

The continent itself is covered by an ice cap ranging in thickness from a few metres to well over a mile (1·6 kilometres) and a recent drilling near the south pole measured 2·6 kilometres. Owing to the presence of this permanent ice cap (its weight depressing the land by as much as two hundred feet or sixty metres), land is only exposed around the edges of the continent or at mountain peaks which protrude through the ice cap. For this reason much of the actual land surface of Antarctica is not directly accessible.

Temperatures as low as -126·9 F ( -88 C) have been recorded at the

Russian research station Vostoc in East Antarctica, although for the rest of the continent, temperatures normally range from -57 F (-49 C) to 5.5 F (-15 C).

Less is known about the Antarctic continent than any of its Gondwanaland relatives, mainly due to its geographical isolation and adverse climate which make expeditions expensive, travelling difficult, restrict the time available for scientific exploration and limit the quantity of material which can be collected.

It is hoped that this Thesis will provide a contribution to our ever increasing knowledge of this vast continent.

## MATERIAL

The three fossil collections were provided by the British Antarctic Survey from material stored in the headquarters at Cambridge.

The collections are diverse, spanning three eras and have accumulated over the past few years.

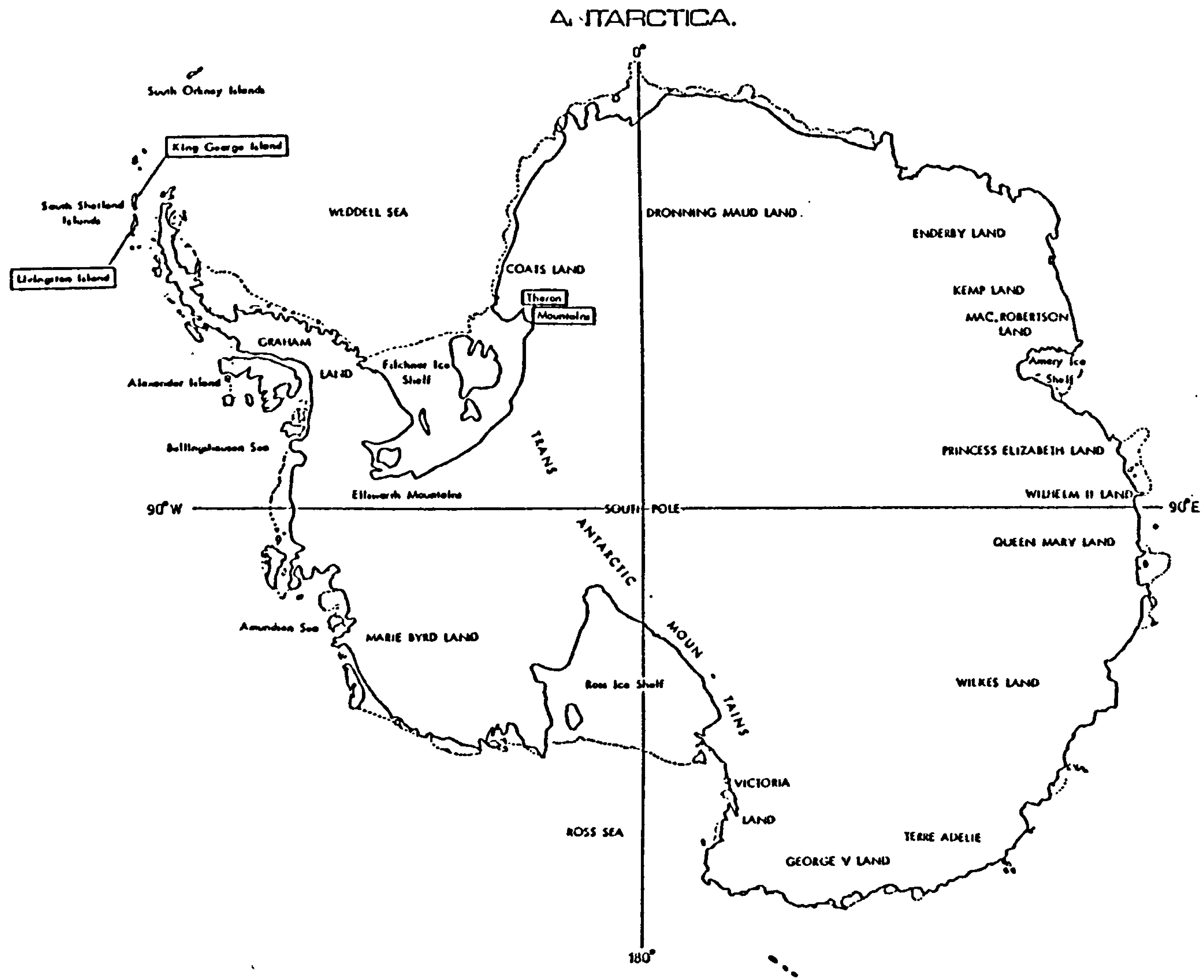
The oldest collection is of Permian age and was collected by Doctor D. Brook from several localities and stratigraphic levels in the Theron Mountains, Coats Land, on the Antarctic mainland.

The second collection is of material of supposed Lower - Mid Triassic age (dated from a previous small collection made by G. J. Hobbs in 1959 and described by Orlando, 1968). It was collected by Doctors M. R. A. Thomson and J. L. Smellie from Williams Point, Livingston Island in the South Shetlands, West Antarctica.

The third collection, made by Doctor C. M. Barton, is of fossil wood from Keller Peninsula, King George Island in the South Shetlands, West Antarctica.

Each of these collections is critically examined and fully described in chapters one to three of this Thesis.

The locations of the Theron Mountains, Livingston Island and King George Island are shown in Text Figure 1.




Text Figure 1: Map of Antarctica showing locations of the Theron Mountains, Livingstone Island and King George Island.

## TECHNIQUES

(See general reviews by Wesley, 1954 and Lacey, 1963).

### OBSERVATIONS

Specimens were observed both wet (under water and xylol) and dry using either a hand lens or a Nikon zoom binocular microscope (magnification of X6 - X60 when using two sets of eyepieces) and illumination was provided by a Watson focussing desk lamp.

Measurements taken on larger specimens were made directly using a millimetre/centimetre graduated ruler. Smaller fossils were first measured with a pair of dividers and the result recorded in millemetres and centimetres.

### DEGAGE TECHNIQUE

A geological hammer was used for both splitting specimens where possible and for breaking up wood fragments that were to be used for stereoscan study. In the latter case the wood chips were first placed in a polythene bag to prevent loss and contamination of the material.

Steel needles were used where necessary to expose fossil matter that was buried in the matrix. This technique was however limited to fossils preserved in fairly soft matrices.

### DRAWINGS

Drawings were first made onto graph paper using four different methods, depending on the size and detail required from the fossil using the strong light source available from the focussing desk lamp.

i. Specimens were sometimes drawn freehand, taking appropriate measurements to ensure accurate reproduction.

ii. Drawings were also made using a half-centimetre etched glass slide in combination with a mounted hand lens or zoom binocular microscope. The idea is that the graduated slide is placed over the fossil, so breaking up the specimen into a large number of small squares, and viewed under a microscope. This image is then copied on to the appropriate size of graph paper. This method is very simple and can provide accurate drawings of such things as secondary venation in small leaves, normally an exceedingly difficult task. (refer to Text Figure 2).

iii. Very small macrofossils were drawn using a Watson Barnett binocular microscope complete with a modified Watson camera lucida attachment, fitted to one side of the microscope only.

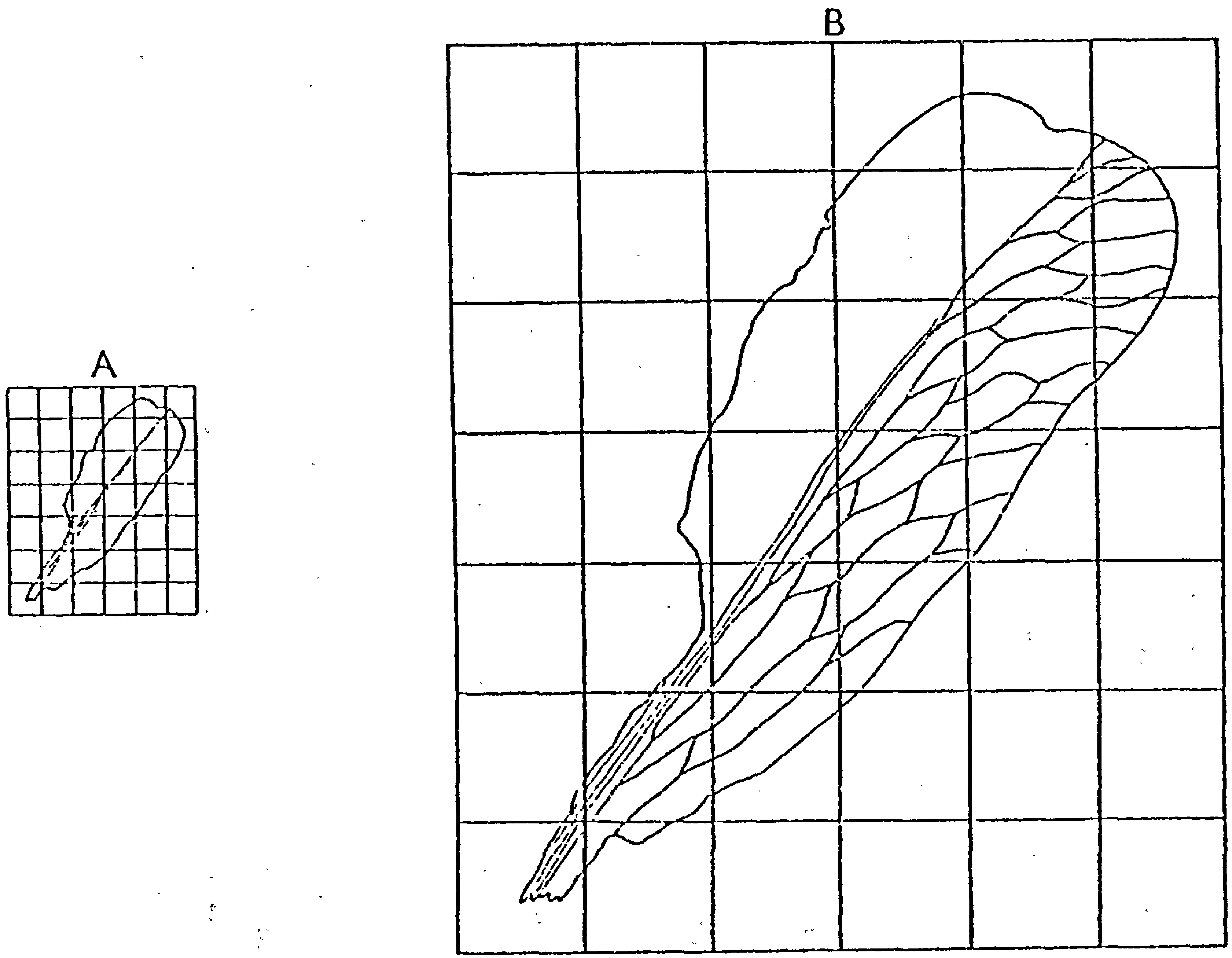
iv. Microfossils were drawn using a Vickers optical microscope with camera lucida attachment.

The finished drawings were transferred onto technical tracing paper using Staedtler 0·25mm., 0·35mm. and 0·5mm. drawing pens. These originals were reduced to the correct size and scales and legends added using 0·35mm. and 0·5mm. Rotring stencils and Letraset.

In the case of the reconstruction of *Hexagonocaulon minutum* (refer to chapter 2), a model was made and the drawing taken from this. A technique of producing three-dimensional diagrams from serial sections using a computer has been put forward (Westbroek, Hesper and Neijndorff, 1976), and this provides very accurate reconstructions.

## SLIDES

Many small specimens were obtained by simply breaking up the original




Text Figure 2: Use of a half-centimetre etched glass slide to produce accurate detailed drawings of small fossils. A indicates actual size. B indicates drawing made through binocular microscope using modified camera lucida attachment and glass slide.

hand specimens or by cutting them out with a small hand saw (the type normally used for resin) where preservation was in a soft matrix. Some of the very small friable material was embedded within transparent 'Strand Glass' resin in order to provide additional strength prior to section making. Larger specimens and rock fragments, including fossil wood were cut up in selected planes with a 'Mottacutta' Mk. II rock cutting machine.

Specimens, if required, were first ground on a 'Cutrock' rotating grinding wheel before being hand polished on a ground glass plate. Grades 60, 400 and 600 carborundum (silicon carbide) powder and Aloxite polishing powder were used.

Etching was carried out using 40% commercial grade Hydroflouric acid in various concentrations for time intervals of between 15 seconds and 3 minutes. This was carried out in a perspex screened fume cupboard, observing the strict safety regulations required when using this dangerous chemical.

After a thorough washing in a water bath, (less violent than immersion under a running tap) the specimens were supported in a gravel box and allowed to dry.

Peels were prepared using the standard peel technique (Joy, Willis and Lacey, 1956) utilising 0·05mm. acetate sheet. Selected areas of the peels were cut out and permanent slides made with Canada Balsam. With the larger peels it was found necessary to use slide clips to keep the peel areas flat. All of the slides were dried on a 'Cutrock' temperature controlled hotplate and left to set.

Slide measurements were made using a Vickers optical microscope and X6 micrometer eyepiece calibrated with a Watson graticule (estimated accuracy of plus or minus 0·5µm.).

## TRANSFERS

(see Cridland and Williams, 1966)

Selected specimens were placed with the fossil facing upwards in small aluminium planchets and covered with transparent 'Strand Glass' resin and left to dry overnight (Leclerq and Noel, 1953). When the planchets were removed, the resulting thin layer of resin on the reverse side of the specimen was ground away to expose the bare rock matrix. The specimens are then placed in poly-ethylene beakers angled against one of the sides with the fossil face upwards and the underlying matrix face downwards.

Hydroflouric acid is then carefully poured into the beaker until the partially resin entombed specimen is covered. As the matrix is eroded away by the acid it falls through the liquid and settles on the bottom of the container. In some cases several changes of Hydroflouric acid combined with some judicious mechanical dislodging of the matrix was required. The specimens were then washed, dried and stored in polythene bags prior to examination.

## SCANNING ELECTRON MICROSCOPY

(see Taylor, 1968)

Wood Fractures: Large wood fragments were broken up using a geological hammer and these were examined with a binocular microscope to select material for stereoscan study (Alvin and Muir, 1969). Smaller fragments were embedded in resin and manipulated to fracture in certain planes by line scoring the resin (Humphrey, Wodzicki and Paulin, 1973).

In all cases the selected fragments were stuck onto stubs using Araldite epoxy resin adhesive (Boyde and Wood, 1969).

Reverse Peels: Peels containing microfossils were stuck face down on to stubs using Evostick adhesive with the organic matter (microspores) face upwards. Little success was met with this unorthodox technique.

Latex Casts: Good quality impressions of fossil leaves were selected by binocular examination. A thin coat of pure rubber latex (L. R. Revultex) was applied to better preserved areas of the impression using a very fine brush, the brush being used to work the rubber in to the surface details and the rubber allowed to dry (Chaloner and Gay, 1973). Silicon rubber has also been used with a lot of success (Watson and Alvin, 1976).

This rubber skin is then peeled off, discarded and the procedure repeated in order to generally clean up the specimen of any dust and loose matrix material which may be present on the surface and would become very apparent under high magnification.

Two thin coats of latex are applied to the clean specimen and allowed to dry. Subsequent coats (up to five) are then made with a latex rubber/filler paste mixture. This dries into a stable, medium hard rubber (the drying speed may be accelerated by placing the specimen under a desk lamp)and provides support to the very thin coat of the pure rubber. Once removed from the specimen, the latex cast can be trimmed with a single edge razor and the casts attached to stubs using Bostik 1 adhesive.

All of the stubs were coated with a thin layer of gold palladium, (Carr, 1971) using either an Edwards vacuum coating unit or a M.7. International Scientific Instrument coating unit and were examined on a Cambridge Steroscan Mk. IIA (operating at 10kV) or on a M.7. International Scientific Instrument Steroscan. All scanning electron micrographs included in this Thesis were taken on the latter machine.

## MICROFOSSILS

(see Chandra, Kar and Lacey, 1977)

Approximately 10 gram samples were taken from selected fragments and placed into poly-ethylene containers where the material was broken up with steel needles. It was then washed in distilled water and bulk macerated using either Hydrofluoric acid or a mixture of Schulze solution and Hydrofluoric acid and left overnight in a fume cupboard.

The residue was washed by continual decanting from one container to another, after topping up with distilled water in order to dilute the acid. In the final stages a pipette was used to draw off the excess liquid to prevent disturbing the sediment. Prior to storage, the resulting slightly acid solutions were neutralised with a weak sodium hydroxide (5%) reagent and then bottled in glass containers.

## PHOTOGRAPHY

Hand Specimens: These were photographed with an F 2·8 Exacta 35mm. camera with a 135mm. lens, extension rings and a 1 - dioptre close-up lens. The camera was attached to a Kodak copying frame. Bellows could not be used because of camera shake and a macro-lens was not available. 25 ASA Panatomic X film was used.

Illumination was provided by a double light bank consisting of 4 x 250 watt bulbs and this was supplemented with a Vickers focussing desk lamp. The specimens were photographed either dry or under water or xylol.

Slides: These were photographed with a Leitz automatic microscope camera with Panatomic X film, using either the built-in variable transmitted light source or in the reflected mode using two of the

Vickers focussing desk lamps positioned either side of the specimen stage with the transmitted light switched off.

Scanning electron microscopy: Photographs were taken with an attached Asahi-Pentax 35mm. camera with a 1:4/50 macro lens, special film and using a cable release. The exposures were timed automatically by the built-in photo indicator lamp.

Printing: Photographs were printed with a Leitz Focomat IC enlarger on bromide single weight paper and developed in a normal strengh solution of DPC developer, fixed in 'Kodafix', washed and glazed on an IBM glazing machine.

All of the plates were made up, scales and numbers added and subsequently rephotographed under glass and printed on A4 paper.

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# CHAPTER ONE

## A PERMIAN FLORA FROM THE THERON MOUNTAINS

# CHAPTER 1

## SUMMARY

A collection of approximately fifty hand specimens from seven sub - collections from the Theron Mountains, Coats Land, Antarctic Mainland has been examined and contains some fourteen taxa.

It includes sphenopsids, cycadopsids (Glossopteridaceae), such as sterile leaves (six species), a possible fertile leaf, cf. Gangamopteris (two species), a scale leaf, Vertebraria indica and seeds.

A single axis of uncertain affinity has also been discovered.

The material is estimated to be of Sakmarian - Artinskian (Lower Permian) age.

# INTRODUCTION

The first remains of Glossopteris leaves, so characteristic of the Permo - Carboniferous Gondwana flora were described by Seward (1914), examining material collected by Doctor Wilson during the ill-fated return from the pole during the Scott expedition of 1912.

Although much of the material was poorly preserved, Glossopteris indica, Glossopteris indica var. wilsoni, scale leaves and doubtful Vertebraria were recognized in the fragments.

This collection was referred to as the most important scientific discovery of the whole expedition (Debenham, 1913).

Fourteen years later a further discovery was made by Edwards (1928) who re-examined material collected on Ferrar's expedition (1901 - 1904) by splitting the original specimens and identifying both Glossopteris indica and Dadoxylon wood.

Since these early discoveries, many sites yielding Glossopteris fossils have been found, confirming beyond doubt that Antarctica has links with Gondwanaland.

The majority of Permo - Carboniferous sites are found in East Antarctica, usually occuring at outcrops along the great Trans - Antarctic mountain chain.

Such material has been described by many, including Darrah (1936, 1941); Plumstead (1962,1964,1975); Kräusel (1962); Schopf (1962,1965, 1967, 1970a, 1970b, 1971, 1973, 1976); Cridland (1963); Grindley (1963); Townrow (1967); Rigby (1969); White (1970); Lambrecht, Lacey and Smith (1973); Kyle (1974) and Lucas (1977).

Few Glossopteris floras have been described in West Antarctica, although an isolated flora has been discovered in the Ellsworth mountain area by Craddock et al. (1965). A flora has also been found in the

Falkland Islands (approximately 1,300 kilometres north of Graham Land) and has been described by Halle (1912), Seward and Walton (1923) and reviewed by Adie (1962).

The Theron mountains are formed of an escarpment 3,000 feet (1,000 metres) high and extend for sixty miles in a general north east to south west direction. At intervals the escarpment is broken by small glaciers which spill over the edge from the ice field above . The highest point attains to some 4,000 feet (1300 metres).

The first plant fossils were collected by Sir Vivian Fuchs during a reconnaisance flight in 1956 and later more extensive collections were made by Stephenson. This material was later described by Plumstead (1962).

## MATERIAL

The material was collected by Doctor D. Brook during geological surveying in the Theron Mountains and consists of fifty hand specimens from seven sub-collections made along the north-west facing exposures (refer to Table 1 and Text Figure 3). Data from Brook (1972).

### TABLE 1

PERMIAN FOSSIL LOCALITIES (from north-east to south-west)

Third Party Material excluded from digitised copy.
Please refer to original text to see this material.

Description of the fossil localities (from north-east to south-west)

Z.487: This is the most prolific locality for plant fossils. The site is seven metres (approximately) below the summit of the ridge on the north-east of Goldsmith Glacier.

Thin, light medium grey, thinly bedded and irregularly laminated coarse grained siltstones containing carbonaceous impressions of leaves and stems (details of leaf venation seen despite the coarseness of the matrix).

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Slightly lower down in the succession there are dark grey-black mudstone shales about two metres thick containing abundant plant impressions both whole leaves and fragmented material. They are preserved as orange and brown carbonized coatings on bedding planes and the cell structure of woody stems is discernible.

Z.508: Thin dark grey-black shales and mudstone partings with abundant leaf and stem impressions occur near the base of the sequence. They occur as dark carbonaceous impressions on bedding planes and much of the fine detail is preserved.

Z.499, Z.472, Z.471 and Z.498: Interbedded with the siltstones and sandstones of Lenton Bluff are coal and plant bearing mudstone and shale horizons, usually about one metre thick but attaining three metres in cases. The aggregate thickness is in excess of twenty metres and most of the fossil material consists of poorly preserved fragmental stems but occasional horizons contain whole leaves with finely preserved detail.

Z.475: Lower fossiliferous horizon at base of Mount Faraway (Coalseam Cliffs). Plant fossils are more frequent and better preserved in the lower part of the succession, at least four coal or fossiliferous horizons being present below the basal sill.

Whole leaves and stems are well preserved and show fine detail as orange and brown carbonized coatings on black mudstone interbedded with dark grey siltstones in two of these horizons but others possess only fragmentary stems.

Refer to Text Figure 4 for sketch map of the Theron Mountains show-positions of the seven fossil sites.

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# SYSTEMATIC DESCRIPTION OF THE FLORA

## SPHENOPSIDA

### Equisetales

### Genus Paracalamites Zalessky 1927

Zalessky erected this genus to include Permian articulated stems and rhizomes having the ribs of the pith cast opposite at each node as in Asterocalamites and not alternating at the nodes.

Rigby (1966a) has proposed a more restricted use of this form genus to include stem fragments frequently referred to as Phyllotheca sp., Phyllotheca deliquescens and Schizoneura sp. from deposits of Lower Gondwana age. He has instituted two species within the genus, notably Paracalamites levis and Paracalamites australis. The former has internodes shorter than the width of the stem and the latter has internodes longer than the width.

### Paracalamites australis Rigby

(Plate 1:1)

Several sphenopsid axes ranging in size from 0·9 centimetres long by 0·4 centimetres wide to 5·7 centimetres long by 1·1 centimetres wide, all with a fine ribbed surface (ribs approximately 1·0 millimetre apart) were recognized in the collection.

These specimens compare well with Paracalamites australis described and figured by Rigby (1969) from Antarctica.

The nodes are either absent from these fragments or else indistinct and the ribbing, when examined under a binocular microscope appears to be composed of even finer striations, which possibly represent the remains of the partially decomposed cellular pattern. Forty to fifty of these striations are found per millimetre and they cover the entire surface of the fossil.

A compression, yielding carbon flakes exhibiting these fine striations was used to provide material for bulk maceration, using both Hydroflouric acid and concentrated Nitric acid to see if any wood fragments or cuticle remains could be obtained. An examination of the diluted residue, however, provided negative results.

One of the better impressions was selected by binocular examination and a latex cast prepared from the specimen. Subsequent examination of the cast under the scanning electron microscope clearly revealed the fine striations on the surface but no further information about the possible cellular pattern could be obtained. This was partly due to the poor preservation which only became apparent under high magnification.

Other axes were present, measuring up to 4·6 centimetres long by up to 3·0 centimetres wide but were poorly preserved and did not reveal a ribbing pattern.

# CYCADOPSIDA

## Pteridospermales

### Glossopteridaceae

### Genus Glossopteris Brongniart 1828

Established by Brongniart to include simple, entire fronds possessing a midrib, with anastomosing and dichotomising secondary venation.

From the outset, this genus, along with its related genera Gangamopteris and Palaeovittaria have been the subject of much debate. These three genera are more or less similar in external form and are usually distinguished from one another by the presence or absence of a midrib and anastomosing of the secondary veins. Glossopteris possesses a distinct midrib and a freely anastomosing secondary vein, forming meshes of great variety. In Gangamopteris there is no midrib but there is free anastomosing of the secondary veins. Palaeovittaria possesses a midrib which is seen only in the lower part of the frond and shows no anastomosing in the secondary veins.

These characters are for typical species only and there is a certain amount of gradation from one form to the next, often leading to some confusion.

The majority of palaeobotanists use a scheme of classification based on gross morphology and secondary venation when identifying specimens (Maheshwari, 1966). This may range from a very loose interpretation as put forward by Arber (1905) who had only thirteen species included in five types of frond to far more rigid ideas of delimiting species as used by Plumstead (1962).

Recently, evidence from cuticles has been used to increase the number of species of Glossopteris nearly twofold, even though the specimens may be morphologically indistiguishable (Surange and Srivastava, 1956; Pant and Gupta, 1968, 1971 and Pant and Singh, 1971). Cuticles have been used as a basis in providing alternative classifications which the authors suggest disprove the more orthodox schemes as species grouped together have different cuticles and some species from different genera have cuticles which are very similar.

A third scheme uses the different type of fructifications associated with the leaves to again construct a so-called natural classification (Plumstead, 1952, 1956 and 1958). This classification not only cuts across the orthodox boundaries, but at the same time does not coincide with the evidence available from cuticles.

Surange (1966) states that of the four types of evidence used in the classification of Glossopteris, notably (i) gross morphology; (ii) venation pattern; (iii) epidermal structure and (iv) types of fructification, all of them seem to disagree with one another. Recently, studies have been made on the epidermal structure of attached fructifications by Chandra and Surange (1976), but not enough evidence is available to include this in classification schemes at present.

Lucas (1977) has described the possibility of a sixth type of evidence using information obtained by the examination of latex casts, prepared from good quality leaf impressions, with the scanning electron microscope.

Stockey and Taylor (1978) have compared rubber moulds with the original surface of cuticles of Araucarites santaecrucis and found that surface artefacts were not formed by trapped air bubbles and that the mould reveals all of the original specimen detail. However, because the specimens from which the moulds were taken had undergone some weathering, the the use of replicas provides a limited amount of information of taxonomic value.

This obviously limits the technique for use with only good quality fossil impressions in order to obtain the most accurate information.

This technique has been used to good effect by Chaloner and Gay (1973); Anderson (1976); DiMichele and Phillips (1976); Watson and Alvin (1976) and Rigby (1978a) and its more widespread application, particularly in the case of Glossopteris, is probably only a matter of time.

White (1978) has put forward a reconstruction of the male cones of Glossopteris linearis McCoy and Glossopteris ampla Dana which shows a whorl of gangamopteroid leaves between the cone and foliage whorl, suggesting that both Glossopteris and Gangamopteris were borne on the same plant, The cone axis, incidentally, revealed a characteristic gymnosperm wood anatomy.

Glossopterid leaves are found throughout the Permo - Carboniferous period and extending into the Triassic, although Delevoryas (1969) has recorded glossopterid leaves from the Jurassic of Mexico. Wesley (1973) suspects that these leaves are nothing more than detached leaflets of Sagenopteris and in fact Darrah (1936) wrongly identified leaves of Glossopteris as Sagenopteris cf. S. plurifolia, a mistake he retracted in a later paper (1941).

The identification of Glossopteris leaves in this Thesis is based solely on gross morphology and venation pattern and undue splitting and lumping have been avoided.

The following taxa have been recognized from the Theron Mountains and are listed in order of frequency.

Glossopteris indica Schimper

Glossopteris communis Feistmantel

Glossopteris browniana Brongniart

Glossopteris angustifolia Brongniart

Glossopteris conspicua Feistmantel

Glossopteris stricta Bunbury

Glossopteris spp.

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An account of these leaves, accompanied by the chief diagnostic characters is outlined in the following notes. Glossopteris leaves are illustrated in Plate 1:4, 2:5 and 2:6 and in Text Figures 5:A - D and 6:A.

Glossopteris indica Schimper

(Plate 1:4 and 2:5)

One of the co-dominant leaf types, with over forty recordings, these leaves ranged in size from 5•0 centimetres long by 1•5 centimetres wide to 8•3 centimetres long by 3•6 centimetres wide. The average dimensions were 6•5 centimetres long by 2•9 centimetres wide.

The specimens are characteristically narrow, elliptic fronds which taper to base and apex. The apex is always acute and specimens up to 30 centimetres have been recorded in the literature.

In the middle the veins are parallel, with one or two median veins reaching the apex without turning aside. The first meshes formed by the lateral veins are polygonal, with two or three rows at an acute angle to the midrib. The veins then turn out at a more oblique angle to the margin, forming parallel, narrow oblong meshes.

Glossopteris communis Feistmantel

(Plate 1:4 and 2:6)

This is the second of the co-dominant frond types with over forty recordings. The leaves measure between 6•0 centimetres long by 1•9 centimetres wide up to 14•3 centimetres long by 3•2 centimetres wide, with an average of 9•1 centimetres long by 2•5 centimetres wide.

Arber (1905) included Glossopteris communis with Glossopteris indica on the grounds that none of the two frond types is constant. However, Rigby (1966, 1978b); Kulkarni (1971) and Kovács - Endrödy (1976) have shown that with careful observations and accurate drawings of the secondary venation, the two species can be distinguished. Confusion has arisen because the variation range of both species (and this is true of many species of Glossopteris) may overlap, making it sometimes difficult to place certain leaves in either species. This would seem insufficient evidence on which to merge the two species.

The frond is usually much narrower than for Glossopteris indica, although both have tapering bases and apices, with the apex always acute. The secondary venation is extremely fine, slightly arching away from the midrib, forming very narrow, oblong meshes of similar size and shape over the whole blade. Published results quote sizes in excess of 20 centimetres for the length of large fronds.

Glossopteris browniana Brongniart

(Plate 1:4)

This species is found much less frequently than either of the two co-dominants, being recorded less than ten times.

Most of the remains are very fragmentary, ranging in size from 1•8 centimetres long by 1•1 centimetres wide up to 5•5 centimetres long by 2•2 centimetres wide with an average of 3•7 centimetres long by 1•8 centimetres wide.

This species is characterized by its great variability in form and the leaves often attain a large size, being narrow elliptic in shape with an often obtuse, contracted apex and distinct midrib. The secondary veins are strongly arched, forming oblong-polygonal meshes of approximately similar size.

Glossopteris angustifolia Brongniart

(Plates 3:9 and 3:10, Text Figure 5:B)

This species was recorded seven times with sizes ranging from 2•4 centimetres long by 0•75 centimetres wide up to 5•1 centimetres long by 0•9 centimetres wide with an average measurement of 3•9 centimetres long by 0•8 centimetres wide.

The leaves are linear, narrow and elongate with an acute or obtusely pointed apex and contracted base. The midrib is well marked and persists almost to the apex. The secondary nerves are oblique, more or less arched near the midrib, then becoming straight, crowded and forming rather narrow, elongate polygonal meshes.

Text Figure 5:B shows one of the better preserved impressions exhibiting the very well marked midrib and oblique secondary veins.

A latex cast was prepared from this specimen and examined under the stereoscan microscope and the results are shown in Plates 3:9 and 3:10.

Plate 3:9 is a low power view of the abaxial surface of the 'leaf', showing the large midrib and dichotomising secondary veins. Plate 3:10 is a high power view of two almost parallel secondary veins very prominent against the low relief of the lamina surface.

Gould and Delevoryas (1977) have described petrified leaves of Glossopteris revealing superb anatomical detail. The midrib consists of a closely spaced reticulum of vascular bundles with a well developed hypodermis on both surfaces along the central reticulum, especially on the abaxial side. The secondary veins of the leaf are supported abaxially and adaxially by fibre-like cells, with a development of palisade (adaxial) and spongy (abaxial) mesophyll between the veins. This information helps towards interpretation of the latex casts made of Glossopteris impressions in a number of ways. The fine striated midrib seen under high power is simply the remains of the grouped vascular bundles and the fibre girders which support the secondary veins explain why these are very often very prominantly preserved (this is especially true for the abaxial surface where there is a greater development of supporting fibres).

During fossilization (notably dehydration and compression), the lamina will shrink considerably and it is likely that the abaxial surface will be greatly deformed as the epidermis contracts over the spongy mesophyll. This deformation, let alone damage due to decomposition, will obviously be very variable and must impose limitations on information retrieved using this technique.

<u>Glossopteris</u> <u>conspicua</u> Feistmantel

(Plates 3:11 and 3:12, Text Figure 5:A)

These were small leaves, ranging in size from 0•8 centimetres long by 0•4 centimetres wide up to 3•2 centimetres long by 0•7 centimetres wide, with an average measurement of 1•7 centimetres long by 0•5 centimetres wide. The species occured approximately seven times in the collection.

The fronds are spathulate or oval lanceolate, with a distinct midrib. The secondary nerves form large open elongate meshes which are approximately the same size throughout the lamina. Meshes are oblong polygonal, transversely elongate and much longer than broad. Text Figure 5:A reveals the best preserved impression of this species and this specimen was used to prepare the latex cast studied in Plates 3:11 and 3:12.

Plate 3:11 shows a low power view of the abaxial surface and reveals very strikingly the coarse meshwork of the secondary veins. The high power view of the vein dichotomy (Plate 3:12) reveals the specimen to be less well preserved than the impression of <u>Glossopteris</u> <u>angustifolia</u> studied earlier. This is interesting because under binocular examination, the <u>Glossopteris</u> <u>conspicua</u> looked superior. In this case the slight weathering has eroded the fine detail that was visible in Plate 3:10.

<u>Glossopteris</u> <u>stricta</u> Bunbury

(Text Figure 6:A)

Only a single specimen was found of this species, measuring 5•6 centimetres long by 2•1 centimetres wide and is illustrated in Text Figure 6:A. The venation was very poorly preserved but could be seen to run almost at right angles from the midrib to the edge of the lamina.

In <u>Glossopteris</u> <u>ampla</u> Dana, the venation is also almost perpendicular to the midrib but the secondary meshes are coarser and the lamina is much wider.

The fronds of Glossopteris stricta are commonly elongate lanceolate in shape with a pointed apex and strong (often grooved) midrib. The fine secondary venation arises from the midrib and diverges across the lamina almost perpendicular to the midrib. Except near the midrib, the secondary veins are numerous and close, forming very narrow and transversely elongate meshes.

Glossopteris spp.

(Text Figure 5:C)

Approximately nine recordings of indeterminate Glossopteris leaves were made and these ranged in size from 1·6 centimetres long by 0·5 centimetres wide up to 4·7 centimetres long by 0·8 centimetres wide. In all cases the secondary venation was indistinct or even absent, making specific identification impossible.

Text Figure 5:C illustrates a typical example, where the midrib has been preserved but there is no trace of secondary venation. The margin of this leaf also appears to have undergone damage prior to fossilization.

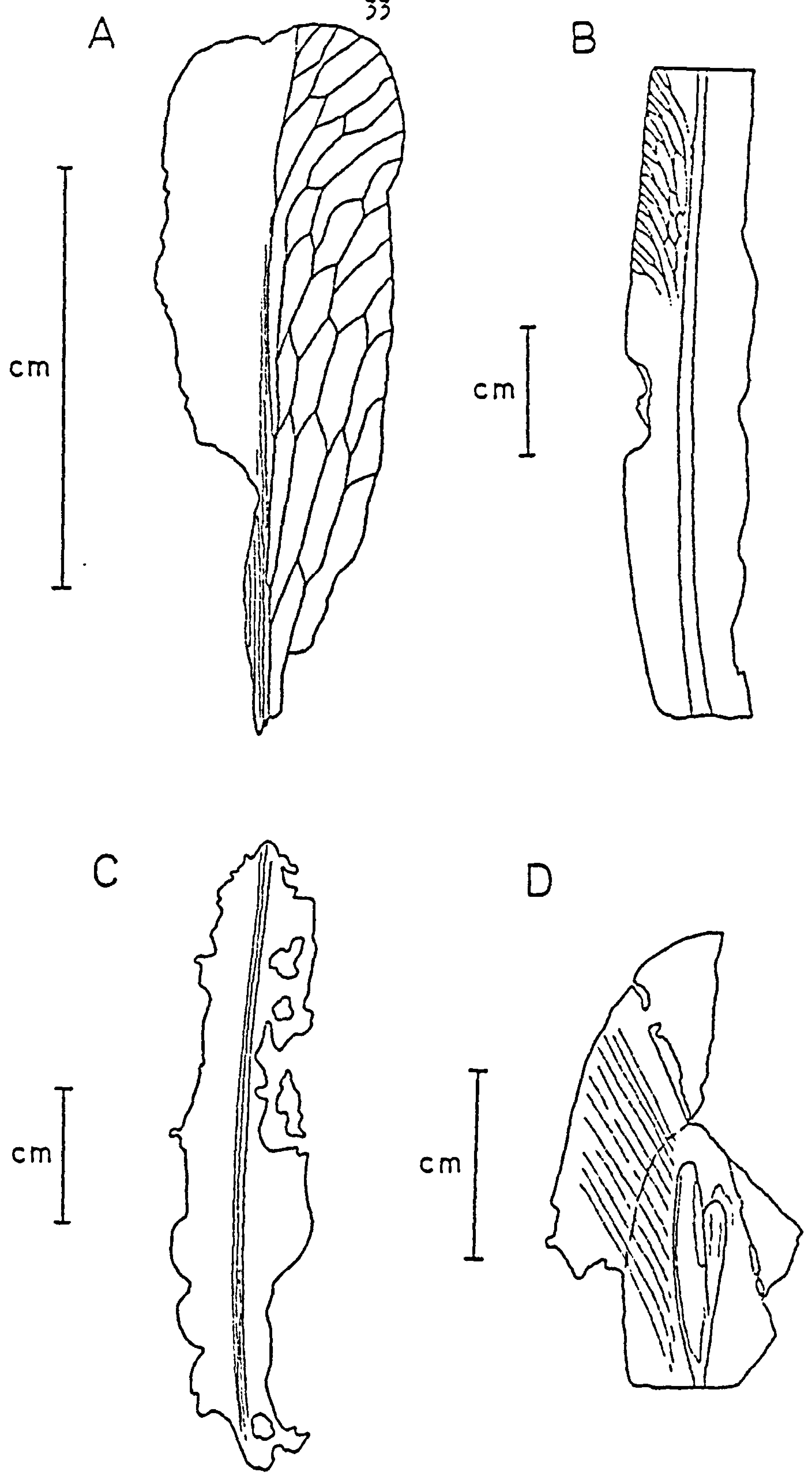
Glossopteris sp. (cf. G. indica) and fructification?.

(Text Figure 5:D)

A single leaf fragment, vaguely resembling the Glossopteris indica type, although poorly preserved, bears what appears to be a smaller leaf covering the main leaf midrib. Along the middle portion of this smaller leaf occurs a raised, single branching protuberance.

The venation, resembling that characteristic of Glossopteris indica, arises from around the protuberance and can be seen to continue to the margin of the larger leaf (ie. it is continuous over both the large and small leaf laminae).

This suggests that although the protuberance itself lies above the larger leaf, the smaller leaf may lie above (ie. thin enough to reveal the midrib and venation of the larger leaf) or underneath the larger




Text Figure 5: A. Glossopteris conspicua, 1·7cm. long x 0·6cm. wide. Specimen Number Z.498.20

B. Glossopteris angustifolia, 5·1cm. long x 0·9cm. wide. Specimen Number Z.498.20

C. Glossopteris sp. 4·4cm long x 0·9cm. wide. Specimen Number Z.487.43

D. Glossopteris sp. and fructification ?. 2·4cm long x 1·55 cm wide. Specimen Number Z.487.16

frond.

Plumstead (1952) has described a fructification called Scutum dutoitides attached to Glossopteris indica, consisting of a short, stiff pedicel attaching the fructification to the top of the petiole, an outer wing and inner raised fertile portion. The wing is thin, smoothly textured and measures overall 3·3 centimetres long by 1·8 centimetres wide. Scutum dutoitides is therefore considerably larger than this possibly fructification.

Kovács - Endrödy (1974) has described seed-bearing Glossopteris leaves (in particular Glossopteris browniana types bearing Cardiocarpus seeds) and these seeds have a thin outer wing (sarcotesta) and an inner thick sclerotesta. The seeds measure 15 - 17 millimetres long and 11 - 12 millimetres wide.

It is likely that this possible fructification may be seed-like in character but the specimen is too poorly preserved to enable further information to be obtained.

## Genus *Gangamopteris* McCoy 1875

*Gangamopteris* is an important member of the Glossopteridaceae and was first described by McCoy in 1847 from Australia. It is probably the oldest member of the *Glossopteris* flora and in all Lower Gondwana deposits it is the first to appear, either alone or mixed with *Glossopteris*. It is this fact which makes it of immense stratigraphical value.

In its gross morphology, *Gangamopteris* appears very similar to *Glossopteris*. It differs , however, in that it has no midrib and the veins are either radiating from the lower median portion of the leaf or forming a group of almost parallel anastomosing veins occupying the position of the midrib.

As with *Glossopteris*, evidence from the type of fructification (Plumstead, 1956) and type of cuticle (Surange and Srivastava, 1956) is in conflict with evidence from gross morphology and venation pattern.

This has led to a suggestion that leaves which possess cuticles and,or, fructifications should be described under different specific names from those leaves which possess neither.

Maithy (1966) claims that although this method might result in nomenclatural duplication, it will nevertheless resolve much of the confusion between cuticular and non-cuticular forms. This is a matter of much debate.

### cf. *Gangamopteris angustifolia* McCoy

(Text Figure 6:C)

A single specimen, measuring 4·4 centimetres long by 0·9 centimetres wide was recognized in the collection.

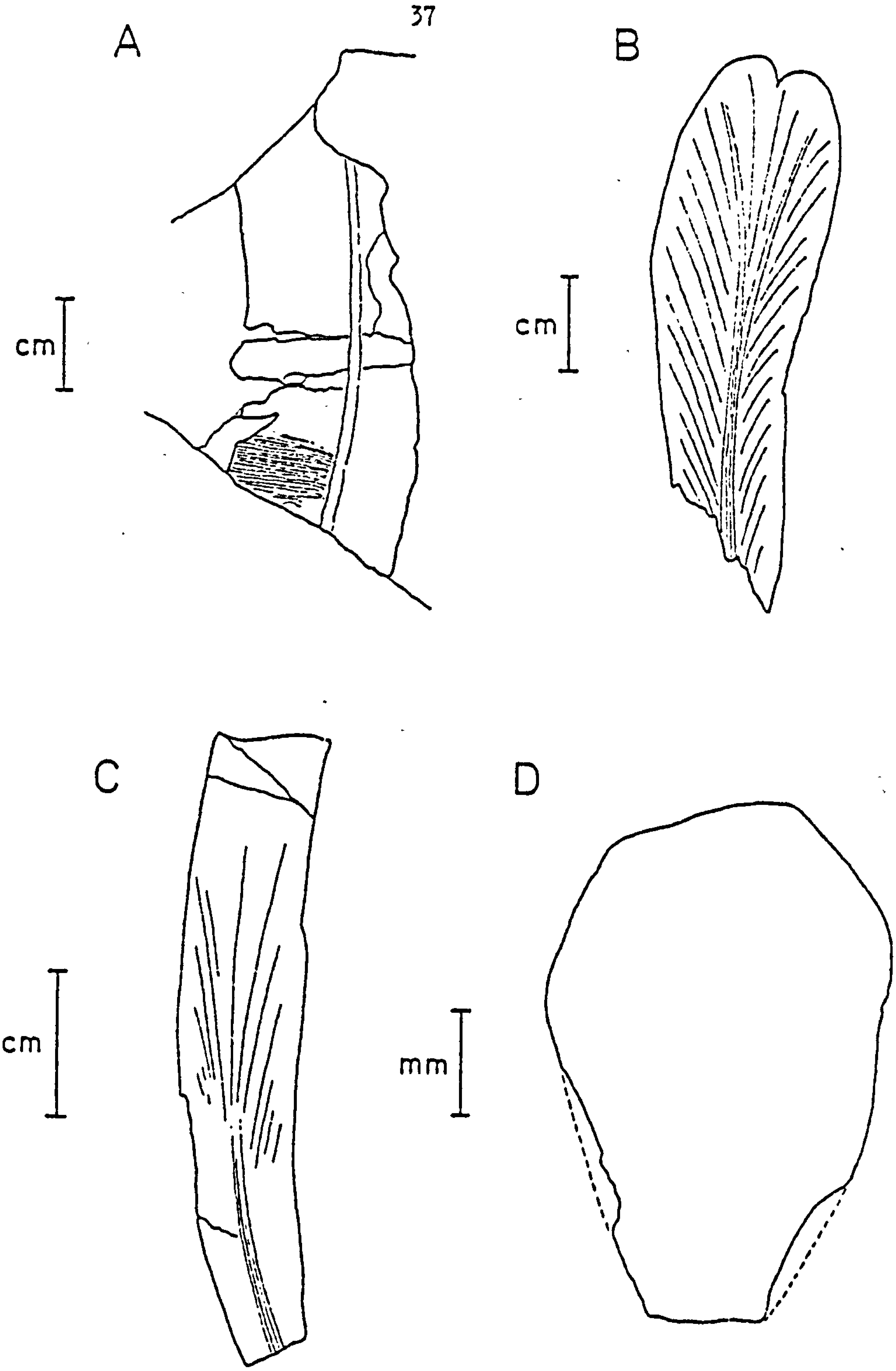
Although the venation was poorly preserved, the overall shape and pattern of the secondary veins is identical to species of *Gangamopteris angustifolia*.

In this species the leaves are linear lanceolate in shape with a well marked median groove. The apparent midrib does not persist for more than one third of the length of the lamina and this was probably much less in the actual specimen as the apex of the frond is missing. This apparent midrib is thereafter replaced by diverging veins which continue to the margin of the leaf.

cf. Gangamopteris spp.

(Text Figure 6:B)

Two complete fronds were recorded, apart from some smaller fragments, one measuring 3•2 centimetres long by 0•6 centimetres wide and the other 5•8 centimetres long by 1•85 centimetres wide. The first specimen was very poorly preserved and yielded little detail. The second specimen (illustrated in Text Figure 6:B) is more interesting as it appears to have a dividing midrib, almost parallel dichotomising secondary venation and an apical notch. It does not compare with any previously described species of Gangamopteris, although the apical notch is reminiscent to some extent of Glossopteris cordata which has a much shorter length frond giving a heart-shaped appearance.




Text Figure 6: A. Glossopteris stricta. 5·6cm long x 2·1cm wide. Specimen Number Z.487.34
B. cf. Gangamopteris sp. 5·8cm long x 1·85cm wide. Specimen Number Z.487.49
C. cf. Gangamopteris angustifolia. 4·4cm long x 0·9cm wide. Specimen Number Z.487.19
D. Scale leaf. 5·0mm long x 3·2mm wide. Specimen Number Z.508.2

## SCALE LEAVES

Scale leaves of Glossopteris were first recognized by Arber (1902) and these have frequently been used as supporting evidence in proposing to merge the two genera Glossopteris and Gangamopteris.

Scale leaves are usually small, have no midrib, possess fine dichotomous and anastomosing venation and are very strongly curved in either a concave or convex shape. They are generally found isolated in the matrix and are thought to serve a protective function (as do bud scales) and may in fact form cones (White, 1978).

### Scale leaf

(Text Figure 6:D)

A single specimen of a scale leaf was recognized in the collection and is illustrated in Text Figure 6:D. The specimen measures 5·0 millimetres long by 3·2 millimetres in width and although no venation was discernable, the small leaf was very strongly convex in shape.

Genus Vertebraria Royle 1840

The genus Vertebraria was founded on impressions of plant axes, some of which, from the evidence of attached roots, were thought to be either large roots or rhizomes.

Vertebraria axes are elongate, flattened, cylindrical casts which may be simple or branched and often bear root-like organs. In specimens preserved parallel to the bedding plane, the cast as seen in surface view is formed of two or three longitudinally disposed series of oblong, almost square areas. Others, less frequently are preserved at right angles to the bedding plane and take the form of a 5 -10 (more commonly 6) armed star-shaped section.

Vertebraria was one of the first genera of fossil to be identified from central Antarctica (Seward, 1914) and its structure, anatomy and interpretation has been the subject of several key papers by Walton and Wilson (1932); Surange and Maheshwari (1960); Schopf (1965, 1971) and Gould (1973).

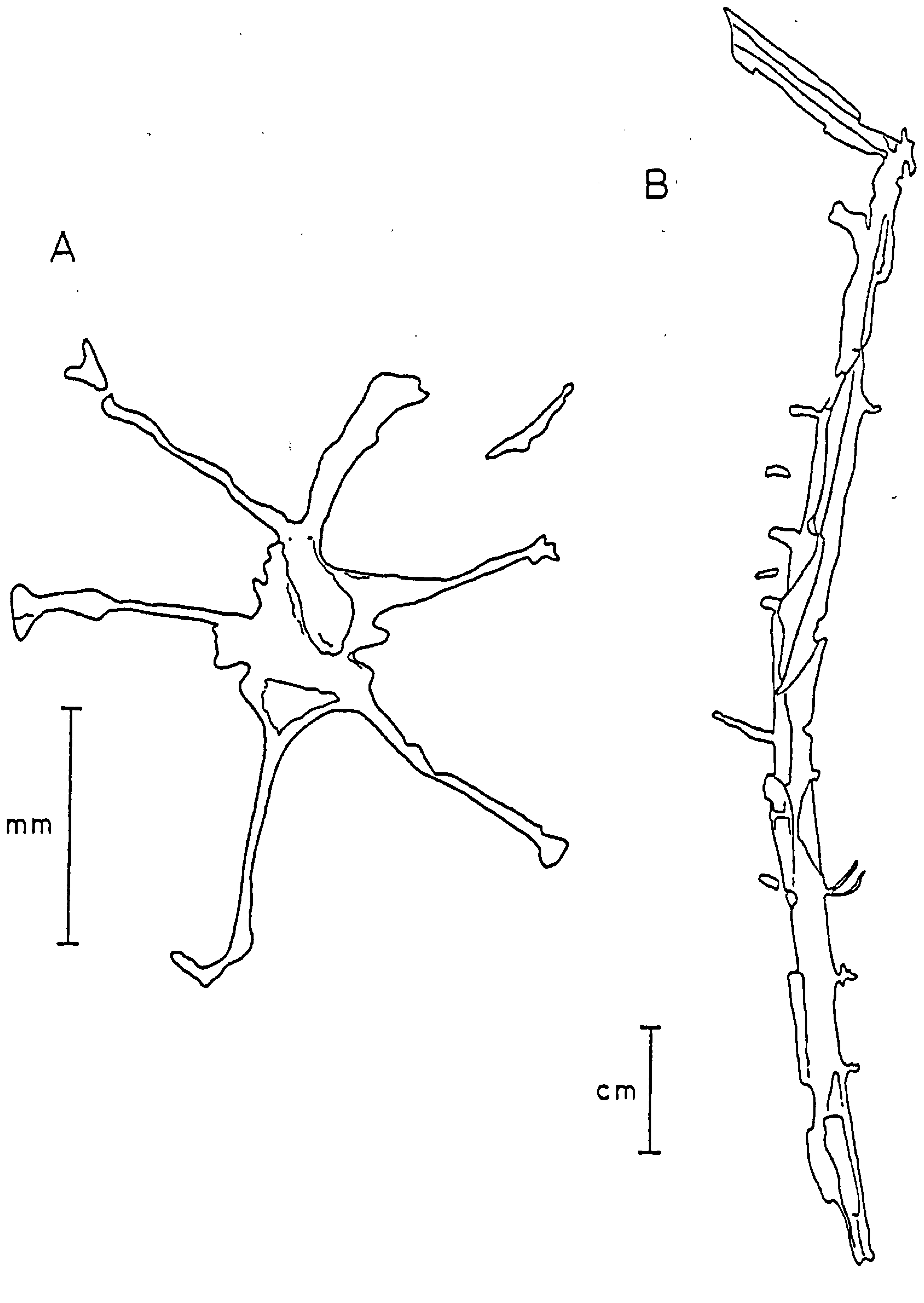
Gould (1973) concludes that the numerous roots arising from the axis, in association with the large spaces (reminiscent of aerenchyma) indicate that Vertebraria was an underground axis or root. It has also been found that the secondary wood of Vertebraria is identical to Araucarioxylon arberi Seward and Araucarioxylon bengalense Holden as described in Maheshwari (1972).

This stongly suggests that Vertebraria was the underground axial system of these trunks, which it is postulated may have borne the foliage of Glossopteris (Schopf, 1970).

Vertebraria indica Royle

(Plates 1:2 and 1:3, Text Figure 7:A and B)

Two types of axis are represented in the collection and these are illustrated in Plates 1:2 and 1:3. The size of the specimens varies from 1·5 centimetres long by 0·1 centimetres wide up to 10 centimetres long




Text Figure 7: A. Vertebraria indica (type b). Transverse section. 3mm wide. Specimen Number Z.487.55
B. Vertebraria indica (type b). 10cm long x 4mm wide. Specimen Number Z.487.55

by 1·2 centimetres wide for type a (Plate 1:2) and 15 centimetres long by 0·8 centimetres wide for the single type b (Plate 1:3) specimen.

The difference between the two types is in the dimensions of the constituent oblong blocks, which are narrower and longer in type b, probably representing a difference in environmental conditions.

Specimens were found in which the block nature of the axis was discernible and this was strikingly revealed in small specimens preserved perpendicular to the bedding plane (refer to Text Figure 7:A). In this particular example, the transverse section reveals six radiating arms.

Text Figure 7:B illustrates a very elongated Vertebraria axis showing large numbers of lateral roots.

As all of the fossils were preserved as thin compressions or impressions, anatomical details could not be studied.

## SEEDS

Isolated seeds are often commonly found in Lower Gondwana collections and the three most frequently recognized are Cardiocarpus Brongniart; Cordaicarpus Geinitz and Samaropsis Goeppert.

These seeds, of various sizes, consist of a central region (nucellus or part of the integument) which can be differentiated from an outer region which forms a wing and may be of varying width.

Genus Samaropsis Goeppert 1864

cf. Samaropsis sp.

(Plate 2:7, Text Figure 8:A and B)

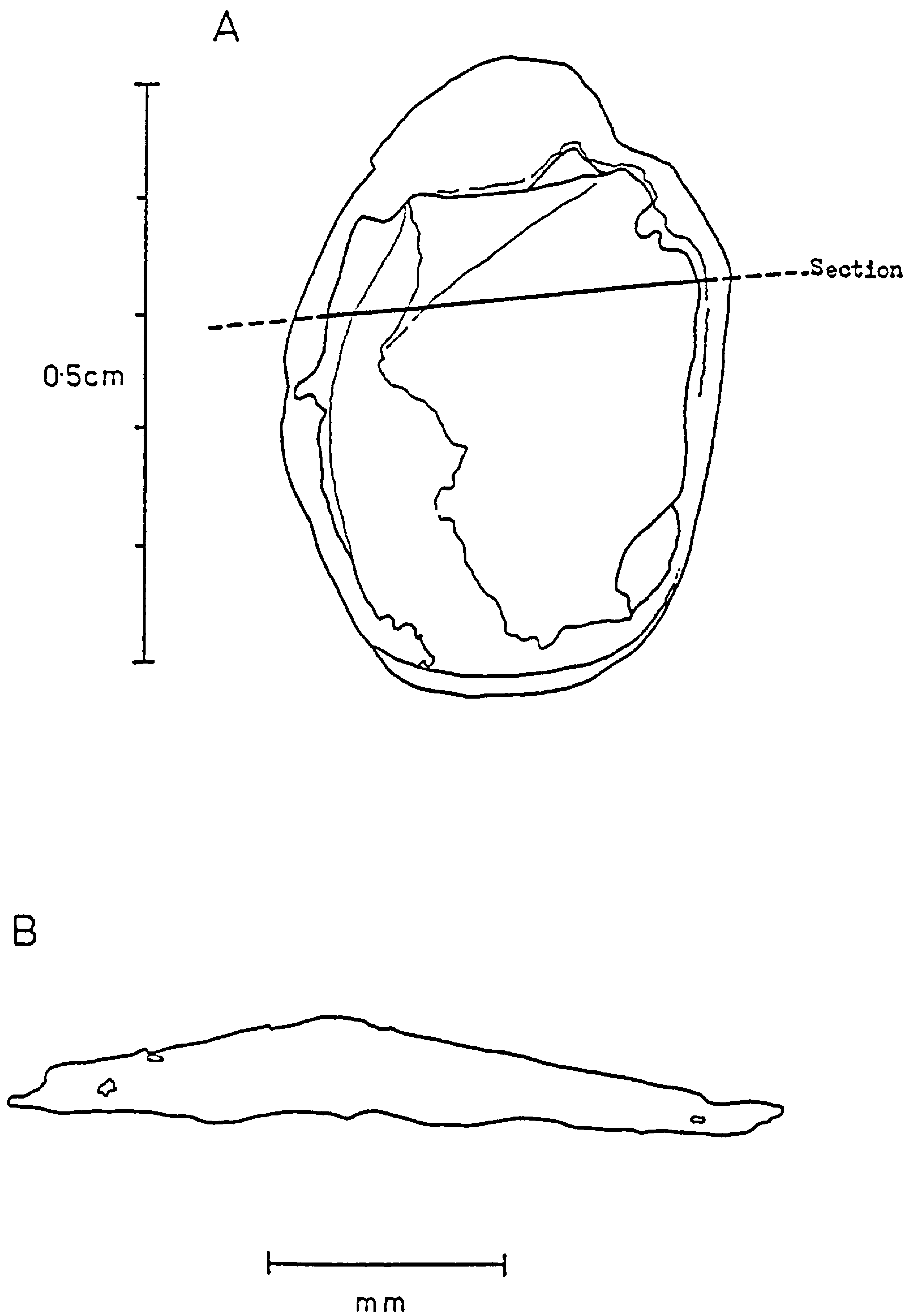
Several small compressions were found of the remains of seeds and in most cases the preservation was very poor.

It was attempted to isolate one of the better preserved examples by bulk masceration but unfortunately this was unsuccesful.

The best preserved specimen is illustrated in Plate 2:7 and Text Figure 8. It measures 0•55 centimetres long by 0•4 centimetres wide with a raised central region 0•35 centimetres long, 0•37 centimetres wide and 0•4 millimetres thick. From these dimensions the seed would appear to possess a very narrow wing (1•5 - 5 millimetres wide) and this may have been caused by shrinkage and,or,decomposition during fossilization.

The thickened central region was removed with steel needles, embedded in resin and sections made using the standard peel technique. From the section (Text Figure 8:B) no internal details could be perceived, except for the possible remains of marginal veins or cavities, but the section does reveal that the seed has undergone considerable compression.

Schopf (1962) has described seeds of Samaropsis longii, which are quite small in size measuring 4 - 5 millimetres in diameter with a central region of 3 - 4 millimetres across and a wing 0•5 millimetres wide.




Text Figure 8: A. Seed. - 0·55cm long x 0·4cm wide. Specimen Number Z.487.42
B. Section through above seed. 3·25mm wide x 0·4mm thick. Specimen Number Z.487.42

These measurements would appear to agree very closely with the seeds from the Theron Mountains and suggest that these seeds may belong in genus Samaropsis. The specimens are too poorly preserved to warrant specific comparisons.

INCERTAE SEDIS

(Plate 2:8, Text Figure 9:A and B)

A single axis, approximately 9•8 centimetres long by 0•7 - 1•0 centimetre wide possesses what appears to be three nodes, with two complete internode sections, 2•8 and 3•4 centimetres in length.

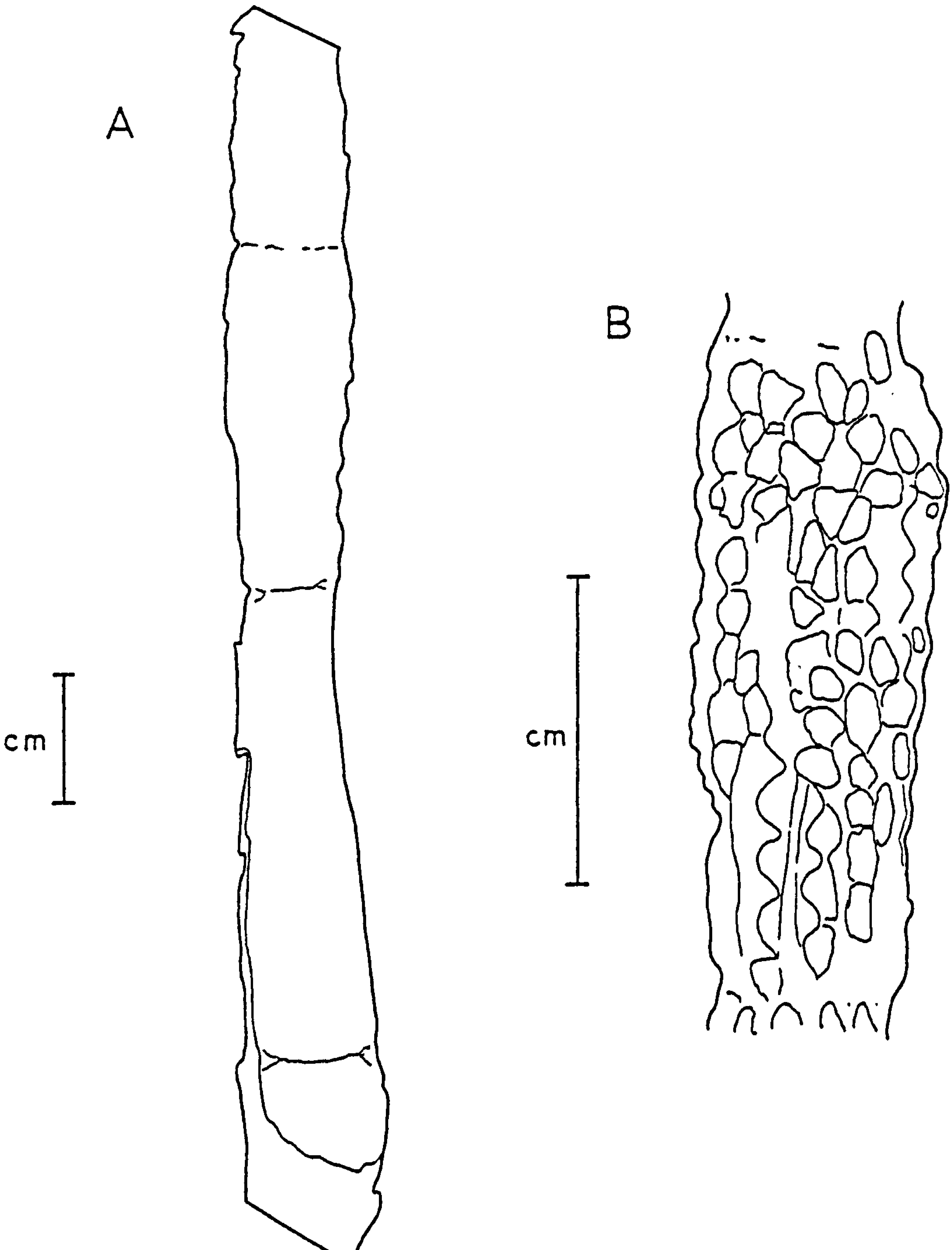
Covering the entire surface, although more noticeable on the two 'upper' internode sections are small scars measuring 1 - 2 millimetres in diameter. They range in shape from almost spherical to longitudinally elongate and even diamond-like in appearance and it is unknown whether these scars were made by leaves, scales or seeds or perhaps a combination of any of the three.

Rigby, J. F. (Lacey, W. S., pers. comm.) rejects the suggestion that it may have been lycopsid as there is no apparent regular phyllotaxis in the arrangment of the scars and he rules out the possibility that it may have been a Cordaite stem or conifer short shoot as the scars do not seem right. He suggests that it may possibly be a fructification of the Dictyopteridium type which has irregular scars but without nodes. It is possible that these may be the result of preservation.

Maheshwari (1965) regards Dictyopteridium as a modified leaf, whereas Surange and Chandra (1973) and Rigby (1978a) regard it as radially symmetrical and possibly cone like. In either of these explanations of Dictyopteridium the maximum length recorded is 4•0 centimetres by 1•0 centimetre wide, much smaller than the axis studied here.

Kendostrobus, a possible male fructification was described by Surange and Chandra(1974) and it is thought to be cone-like, but again it measures only 4•0 centimetres long and 0•5 centimetres wide.

Surange, K. R. (Lacey, W. S., pers. comm.) comments that the axis does not look like any fructification of Glossopteris (as the margins of fructifications are always distinct, regular and smooth) and does not look




Text Figure 9: A. Axis. 9·8cm long x 0·7 – 1·0cm wide. Specimen Number Z.508.3
B. Detail of axis internode section. Scars 1 – 2mm in diameter. Specimen Number Z.508.3

likely to be a cone or lycopod. He concludes that the axis may represent an apical shoot which has shed its spirally arranged leaves.

White (1978) has described a partially petrified axis bearing linear-lanceolate leaves of Glossopteris linearis arranged in whorls on a close spiral, a whorl of modified, small gangamopteroid leaves and a terminal male cone. The axis is over 11·0 centimetres long and tapers from a width of 2·0 centimetres.

Smithies (1978) has described an axis from the Lower Permian of South Africa which has diagonal rows of small, well spaced, transversely orientated lenticular to rhomboid scars. The axis measures over 24·0 centimetres long and up to 2·8 centimetres wide. She regards the axis as having lycopod affinities.

It is possible that the axis described here represents the incomplete remains of a terminal shoot of a Glossopteris plant after it has shed all of its leaves, scales or cone. The nodes could represent the growth scars of the branchlet.

## MICROFOSSILS

Samples were made by bulk masceration from three rock specimens: numbers Z.472.14, Z.471.3 and Z.475.3B although microfossils could only be obtained from Z.472.14.

Phylum Protozoa

Class Gymnomyxa (Sarcodina)

Order Foraminifera

Two or possibly three types of animal fossil were recognized and are the remains of very small amoeboid organisms which possessed a shell and are included in the diverse order Foraminifera.

Two distinct forms of Foraminifera are recognized; a porcellanous form in which the shell is calcareous, porcellanous and not perforated by canals but provided with one or two large apertures through which the pseudopodia protrude and a calcite form in which the shell is perforated by numerous canals for the passage of pseudopodia.

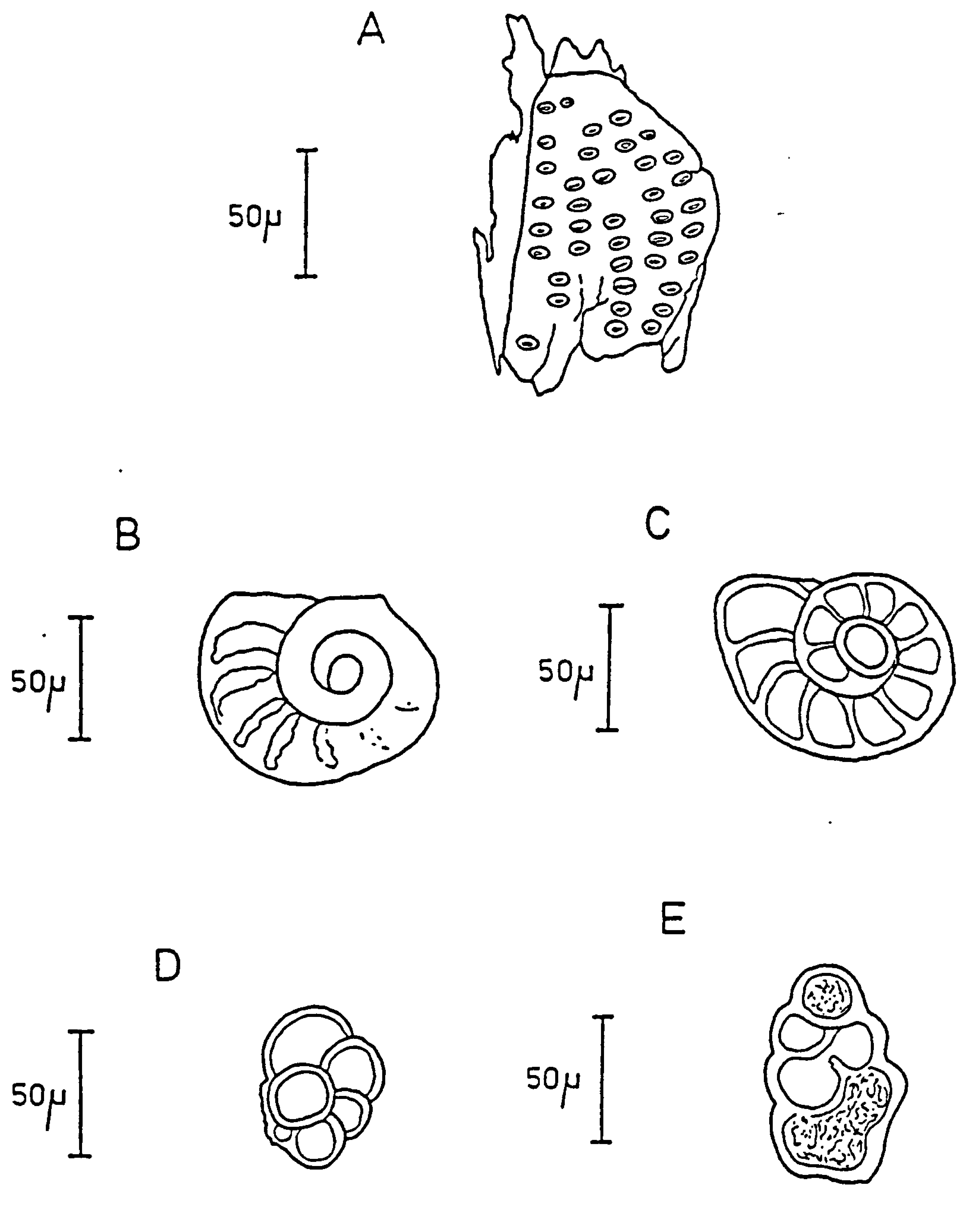
In general, six characters are used in the identification of both living and fossil specimens. These deal with the general appearance; size, number and arrangement of the chambers; shape of the sutures; composition, thickness and perforations of the wall; relationship and position of the aperture and colour (not usually evident in the fossil form).

Foraminifera spp.

(Text Figure 10:A - E)

In total, five specimens were recognized and these are all illustrated in Text Figure 10. Four of them are of the calcite form (Text Figure 10: B - E) and only one of the porcellanous form (Text Figure 10:A).

Identification has proved very difficult and has been restricted to making comparisons with illustrations in Cushman (1950) and Moore (1964).




Text Figure 10: A. Foraminifera sp. (type a) 158μm long x 98μm wide. Specimen Number Z.472.14
B. Foraminifera sp. (type b). 90μm x 75μm in diameter. Specimen Number Z.472.14
C. Foraminifera sp. (type b). 100μm x 82μm in diameter Specimen Number Z.372.14
D. Foraminifera sp. (type b or c). 65μm x 48μm in diameter. Specimen Number Z.472.14
E. Foraminifera sp. (type b or c). 86μm x 60μm in diameter. Specimen Number Z.472.14

Moore (1964) lists four orders and these are Textulariina, Fusulinina, Miliolina and Rotalina plus an Incertae Sedis group.

The fossils appear to have more in common with representatives of the Fusulinina, although comparisons can also be made to a lesser extent with the Rotalina. Within the Fusulinina, Foraminifera types b and c illustrated in Text Figure 10:B - E could be included in the family Endothyridae as they share many characteristics with the genera _Endothyra_ and _Biseriammina_.

Although this must be regarded only as a tentative classification, since few specimens were found and were not all that well preserved, it has raised an interesting point as the Fusulinina (which is represented by extinct families only) has not been found in Antarctica (Moore, 1964).

## DISCUSSION

The following lists are of taxa recognized from the seven sub-collections from the Theron Mountains, Antarctica as described in chapter one of this Thesis. Those species marked with an asterisk indicate a new record for the locality.

Collection Number Z.487

* Glossopteris indica Schimper

* Glossopteris communis Feistmantel

Glossopteris browniana Brongniart

* Glossopteris angustifolia Brongniart

* Glossopteris conspicua Feistmantel

Glossopteris stricta Bunbury

Glossopteris spp.

Glossopteris sp. and fructification ?

* cf. Gangamopteris angustifolia McCoy

* cf. Gangamopteris sp.

Vertebraria indica Royle

* cf. Samaropsis sp.

Axes (indeterminate)

Collection Number Z.508

* Glossopteris indica Schimper

* Glossopteris communis Feistmantel

Glossopteris browniana Brongniart

* Glossopteris angustifolia Brongniart

* Glossopteris conspicua Feistmantel

Glossopteris sp.

* cf. Gangamopteris sp.

Vertebraria indica Royle

Scale leaf

Axis (possibly of Glossopteris)

Collection Number Z.499

* Paracalamites australis Rigby

Collection Number Z.472

Glossopteris indica/communis

Glossopteris indica/browniana

* Glossopteris conspicua Feistmantel

* Foraminifera spp.

Collection Number Z.471

Glossopteris browniana/conspicua

Collection Number Z.498

* Glossopteris angustifolia Brongniart

* Glossopteris conspicua Feistmantel

Glossopteris sp.

Vertebraria indica Royle

Collection Number Z.475

Vertebraria indica Royle

Organic remains ?

Z.487 is by far the largest sub-collection and contains ten out of the total of the thirteen or more taxa recognized from all of the sub-collections. It would appear to be almost identical in composition with the other large sub-collection Z.508 which is from a similar horizon.

In combination, Z.487 and Z.508 represent the bulk of the entire collection and include all but two of the taxa.

The other collections which are all from lower horizons are too small and contain too few taxa for any effective comparisons to be made.

Complete fossil flora (all represented in Z.487 and Z.508 except for those species marked with a dash).

- Paracalamites australis Rigby
  Glossopteris indica Schimper
  Glossopteris communis Feistmantel
  Glossopteris browniana Brongniart
  Glossopteris angustifolia Brongniart
  Glossopteris conspicua Feistmantel
  Glossopteris stricta Bunbury
  Glossopteris sp. and fructification ?
  cf. Gangamopteris angustifolia McCoy
  cf. Gangamopteris sp.
  Scale leaf
  Vertebraria indica Royle
  cf. Samaropsis sp.
  Axis (possibly of Glossopteris)
  Axes (indeterminate)
- Foraminifera spp.

COMPOSITION

The flora is characterized by a domination of cycadopsid leaves, in particular species belonging to Glossopteris indica and Glossopteris communis. Glossopteris browniana, Glossopteris angustifolia and

Glossopteris conspicua are represented to a much lesser extent, with Glossopteris stricta being extremely rare.

Seeds (cf. Samaropsis sp.), scale leaves and species of Gangamopteris are also uncommon and there is a complete absence of lycopsids, pteropsids, coniferopsids and northern elements of any kind.

Vertebraria indica, although found in three of the sub-collections is only locally abundant (ie. occurs on only a few hand specimens).

## COMPARISONS WITH OTHER FLORAS FROM ANTARCTICA

(refer to Table 2)

Plumstead (1962) has desribed floras from three levels in the Theron Mountains and a larger, richer flora from the nearby Whichaway Nunataks. The smaller Theron Mountain collections have five taxa in common with the present material, these being Phyllotheca australis (re-determined by Rigby, 1969 as Paracalamites australis), two species of Glossopteris, scale leaves and Vertebraria indica.

The Whichaway Nunatak flora has six taxa in common, including four species of Glossopteris, Gangamopteris angustifolia and Vertebraria indica.

White (1970) has described a flora from the Prince Charles Mountains in MacRobertson Land having four taxa in common, including Gangamopteris angustifolia.

Other floras which compare with the present collection include the Buckley Coal Measure flora (Grindley, 1963) and Law Glacier area flora (Lambrecht, Lacey and Smith, 1973 and Lucas, 1977) which have four to six taxa in common but do not contain Gangamopteris angustifolia.

## COMPARISONS WITH OTHER FLORAS FROM THE REST OF GONDWANALAND

(refer to Table 3)

Africa: The flora compares with the Mid - Ecca of South Africa as

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● = taxa in common.

| | Paracalamites australis | Glossopteris indica | Glossopteris communis | Glossopteris browniana | Glossopteris angustifolia | Glossopteris conspicua | Glossopteris stricta | Gangamopteris angustifolia | Vertebraria indica | Scale leaves | Samaropsis sp. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| L. Beaufort, S. Africa | | ● | | ● | ● | ● | | | | ● | ● | |
| U. Ecca, S. Africa | | ● | | ● | ● | | ● | | | ● | ● | Lacey et al (1975) |
| M. Ecca, S. Africa | ● | ● | ● | ● | ● | | ● | | ● | ● | ● | Le Roux & Anderson (1977) |
| L. Ecca, S. Africa | | ● | ● | ● | | | | | | | | |
| Wankie, Rhodesia | | ● | | ● | ● | | ● | | ● | ● | | Lacey & Huard-Moine (1966) |
| Tete, Mozambique | ● | ● | ● | ● | ● | | ● | | | ● | | Oliveira (1972, 1975) |
| Luangwa, Zambia | | ● | ● | ● | | | ● | | | ● | | Lacey & Smith (1972) Lucas (1977) |
| Tangadzi, Malawi | | ● | | ● | ● | | ● | | ● | ● | | Lacey & Kulkarni (1969) |
| | | | | | | | | | | | | |
| U. Coal, N.S.W. | ● | | | ● | | | | | | ● | | Rigby (1966a) |
| L. Coal, N.S.W. | ● | ● | | ● | ● | ● | | | | | ● | Walkom (1928) |
| U. Bowen, Queensland | ● | ● | | ● | ● | ● | | | ● | ● | ● | Hill (1952), Rigby (1962) |
| L. Bowen, Queensland | ● | ● | ● | ● | | | | ● | ● | ● | ● | Walkom (1922) |
| Kaloola, Queensland | ● | ● | ● | ● | ● | | | | ● | ● | ● | Rigby (1972a) |
| Perth & Collie, W. Aust. | ● | ● | ● | ● | | | | | ● | ● | ● | Rigby (1966b) |
| U. Coal, Tasmania | ● | | | | | | | | | | | Oliveira (1975) |
| L. Coal, Tasmania | ● | | ● | ● | | | | | | | | |
| | | | | | | | | | | | | |
| Bajo de la Leona, Argent. | | ● | | ● | | | ● | ● | | | | |
| Serie Bonete, Argentina | ● | ● | | ● | | | ● | | | | | Archangelsky (1958,1965,196 |
| Bajo de los Velez, Argent. | ● | ● | | ● | | | | | | | | Archangelsky & Arrondo (1970 |
| Nueva Lubecka, Argentina | ● | ● | | ● | ● | | | | | | | Rigby (1972b) |
| Rio do Rasto, Brazil | ● | ● | | ● | | | | | | | | |
| Est. Nova, Brazil | ● | | ● | | | | | ● | ● | ● | | Mendes (1952) |
| Irati, Brazil | ● | ● | | ● | | | ● | | | | | Rigby (1972b) |
| Guatá, Brazil | ● | ● | ● | ● | ● | | ● | ● | | ● | ● | Rösler (1975a,1975b,1978) |
| Itararé, Brazil | ● | ● | ● | | | | | | | | | White (1908) |
| | | | | | | | | | | | | |
| Raniganj, India | ● | ● | ● | ● | ● | ● | ● | | ● | ● | ● | Kulkarni (1971) |
| Barren Measures, India | ● | ● | ● | ● | ● | ● | | | ● | | | Lele (1976) |
| Barakar, India | ● | ● | ● | ● | | | ● | | ● | ● | | Maheshwari (1976) |
| Karharbari, India | ● | ● | ● | ● | ● | | ● | ● | ● | ● | ● | Maithy (1965) |
| Talchir, India | ● | ● | ● | | | | | ● | ● | | ● | Surange (1975) |
| | | | | | | | | | | | | |
| Lafonian, Falkland Is. | | ● | | ● | ● | | | ● | | ● | | Halle (1912) Seward & Walton (1923) |

Table 3. Comparison with other floras from the rest of Gondwanaland

described by Oliveira (1975) and le Roux and Anderson (1977); the Upper Wankie district of Rhodesia (Lacey and Huard - Moine, 1966); the Tete region of Mozambique (Oliveira, 1972, 1975); the Upper Luangwa valley in Zambia (Lacey and Smith, 1972 and Lucas, 1977) and with the flora from the Tangadzi River in Malawi (Lacey and Kulkarni, 1969).

Australia: The flora compares with the Lower (Greta) Coal Measures of New South Wales (Walkom, 1928 and Rigby, 1966 ); the Lower Bowen Series of Queensland (Walkom, 1922; Hill, 1952 and Rigby,1962); the Perth and Collie Basin in West Australia (Rigby, 1966b) and with the Lower Coal Measures of Tasmania (Oliveira, 1975)

South America: The flora compares with the Bajo de la Leona Series of Santa Cruz in Argentina (Archangelsky, 1958, 1965, 1968 and Rigby, 1972b) and with the Guatá Formation of Brazil (Rigby, 1972b and Rösler, 1978).

India: The flora compares with the Karharbari Stage of the Lower Gondwana and also with the younger Raniganj Stage, although Gangamopteris angustifolia occurs only in the former (Surange, 1975; Lele, 1976 and Maheshwari, 1976).

Falkland Islands: The flora compares with that from the Lafonian System of East Falkland (Halle, 1912 and Seward and Walton, 1923).

## AGE

(refer to Table 4)

The collection is of undoubted Permian age and compares with many floras from Antarctica and from the rest of Gondwanaland.

Gangamopteris angustifolia is confined to lower horizons in the Permo - Carboniferous era (Du Toit, 1954) and Plumstead (1962) states that the presence of Gangamopteris indicates that the rocks may safely be regarded as not younger than of Lower Permian age. This is disputed by White (1970) who states that although the large Gangamopteris leaves of cyclopteroides type were extinct by the Upper Permian, this is not

| | CARBON. | PERMIAN | | | | | TRIASSIC |
|---|---|---|---|---|---|---|---|
| | Stephanian | Sakmarian | Artinskian | Kungurian | Kazanian | Tartarian | Lower Triassic |
| S.Africa | | L. Ecca (6) | M. Ecca (9) | U. Ecca (7) | Lower Beaufort (6) | | |
| Mozambique | | | Tete (7) | | | | |
| Rhodesia | | | Wankie (6) | | | | |
| Malawi | | | Tangadzi (6) | | | | |
| Zambia | | | Luangwa (5) | | | | |
| N.S.W. | | L. Coal (6) | | | | U. Coal (3) | |
| Queensland | | | | | | Kaloola (8) | |
| Queensland | | L.Bowen (8) | | | | U. Bowen (8) | |
| W.Australia | | | Perth & Collie (7) | | | | |
| Tasmania | | Lower Mersey Coal (3) | | | Upper Mersey Coal (1) | | |
| Argentina | | | S.Bonete (4) | | | | |
| Argentina | | B.de la Leona (4) | | | | | |
| Argentina | | | Nueva Lubecka (4) | | | | |
| Argentina | | B. de los Valez (3) | | | | | |
| Brazil | Itar. (5) | | Guatá (9) | Iruti (4) | Est. Nov (5) | Rio Rasto (3) | |
| India | | Talchir (6) | Karharb. (10) | Barakar (7) | B. Meas. (7) | Raniganj (10) | |
| Falklands | | | Lafonian (5) | | | | |

Table 4. Stratigraphic correlation of Lower Gondwana floras
(Number of common taxa shown in brackets).

true for the smaller leaved angustifolia type and that Gangamopteris angustifolia has been found in the Upper Permian Bandanna Formation in Queensland, Australia (White, 1961).

In the present collection there is an absence of so-called advanced Glossopteris leaves such as Glossopteris elongata (syn: Glossopteris retifera) which are commonly found in the upper horizons.

The majority of the species are of little stratigraphical value (Archangelsky, page 6, 1958) and are more usefully thought of as a group and compared with other assemblages.

The present flora from the Theron Mountains compares very well with the Mid - Ecca and Tete floras of Africa (Sakmarian - Artinskian); the Greta, Lower Bowen and Perth & Collie floras of Australia (Sakmarian - Artinskian/Kungerian); the Bajo de la Leona and Guatá floras of South America (Sakmarian - Kungerian) and with the Karharbari flora of India (Artinskian).

It is suggested that the present flora is of Lower Permian (Sakmarian - Artinskian) age.

## ENVIRONMENT

Eighty-two percent of the collection is made up of fronds of Glossopteris, the remaining eighteen percent including seeds and assorted axes and are all included in seven genera.

Some of the blocks (Z.508.2) contain a large assemblage of overlapping leaves in a fairly fragmented state. This is also true to a certain extent with the axis remains. This suggests that the material may have been transported some distance prior to deposition and subsequent fossilization in much slower moving waters. The presence of Foraminifera in the strata reveal the lacustrine environment to have been biologically active and probably not far from the fossil beds.

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PLATE 1

Plate 1·1 Paracalamites australis. 1·0cm. wide.

Specimen Number Z.499.8

Plate 1·2 Vertebraria indica (type a). 1·9cm. wide.

Specimen Number Z.487.55

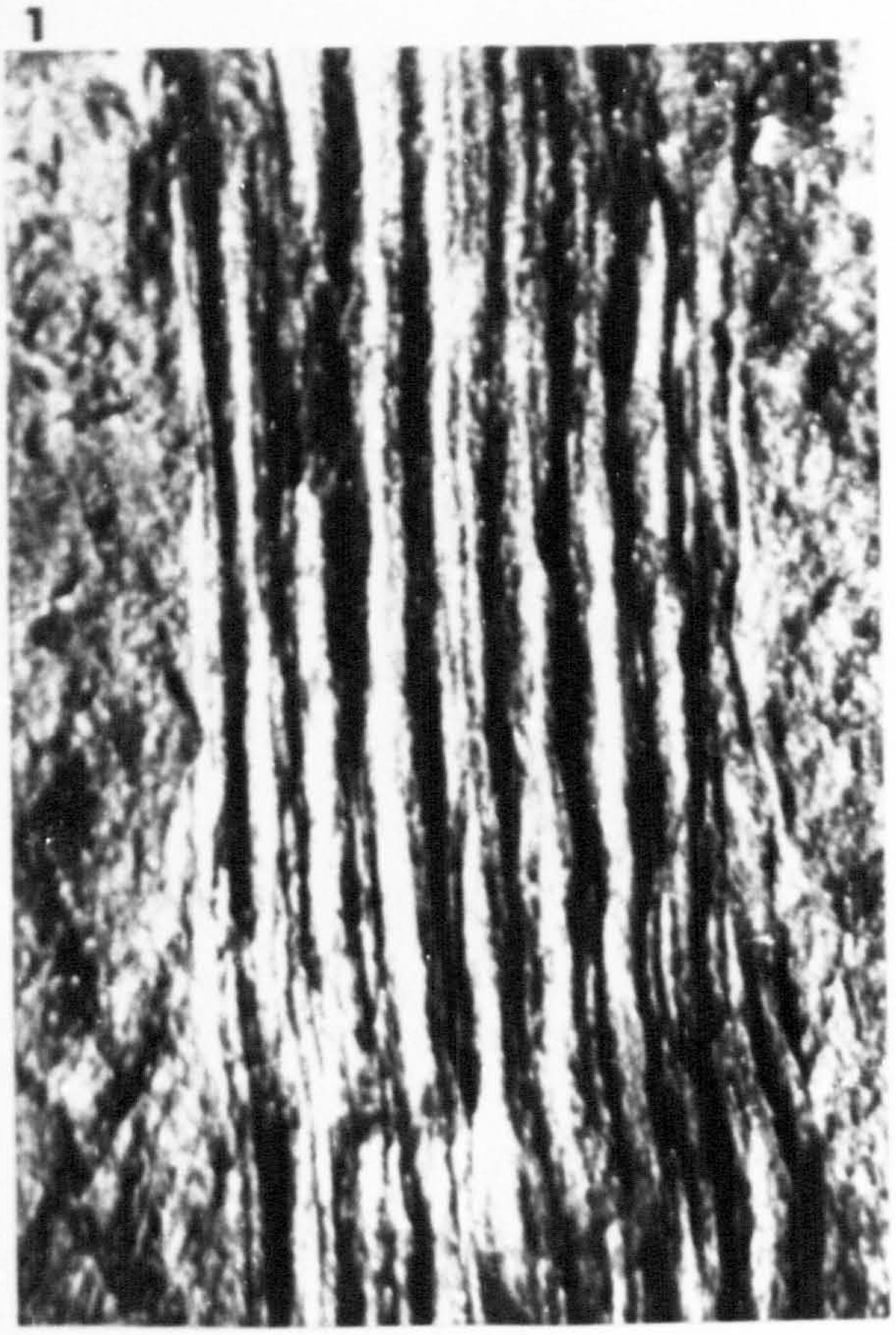
Plate 1·3 Vertebraria indica (type b). 1·3cm. wide.

Specimen Number Z.475.4

Plate 1·4 Glossopteris spp. From top to bottom, fragment of Glossopteris cf. indica/browniana, Glossopteris indica and three specimens of Glossopteris communis type.

Specimen Number Z.487.51

1



cm.

2

cm.

3

cm.

4

cm.

PLATE 2

Plate 2·5 <u>Glossopteris</u> <u>indica</u>. 5·8cm. long x 2·5cm. wide.

Specimen Number Z.487.32

Plate 2·6 <u>Glossopteris</u> <u>communis</u>. 7·3cm. long x 2·0cm. wide.

Specimen Number Z.487.49

Plate 2·7 Possible seed. 0·55cm. long x 0·4cm. wide.

Specimen Number Z.487.42

Plate 2·8 Internodal? section of axis of uncertain affinity.

2·8cm. long x 0·95cm. wide.

Specimen Number Z.508.3

5

cm.

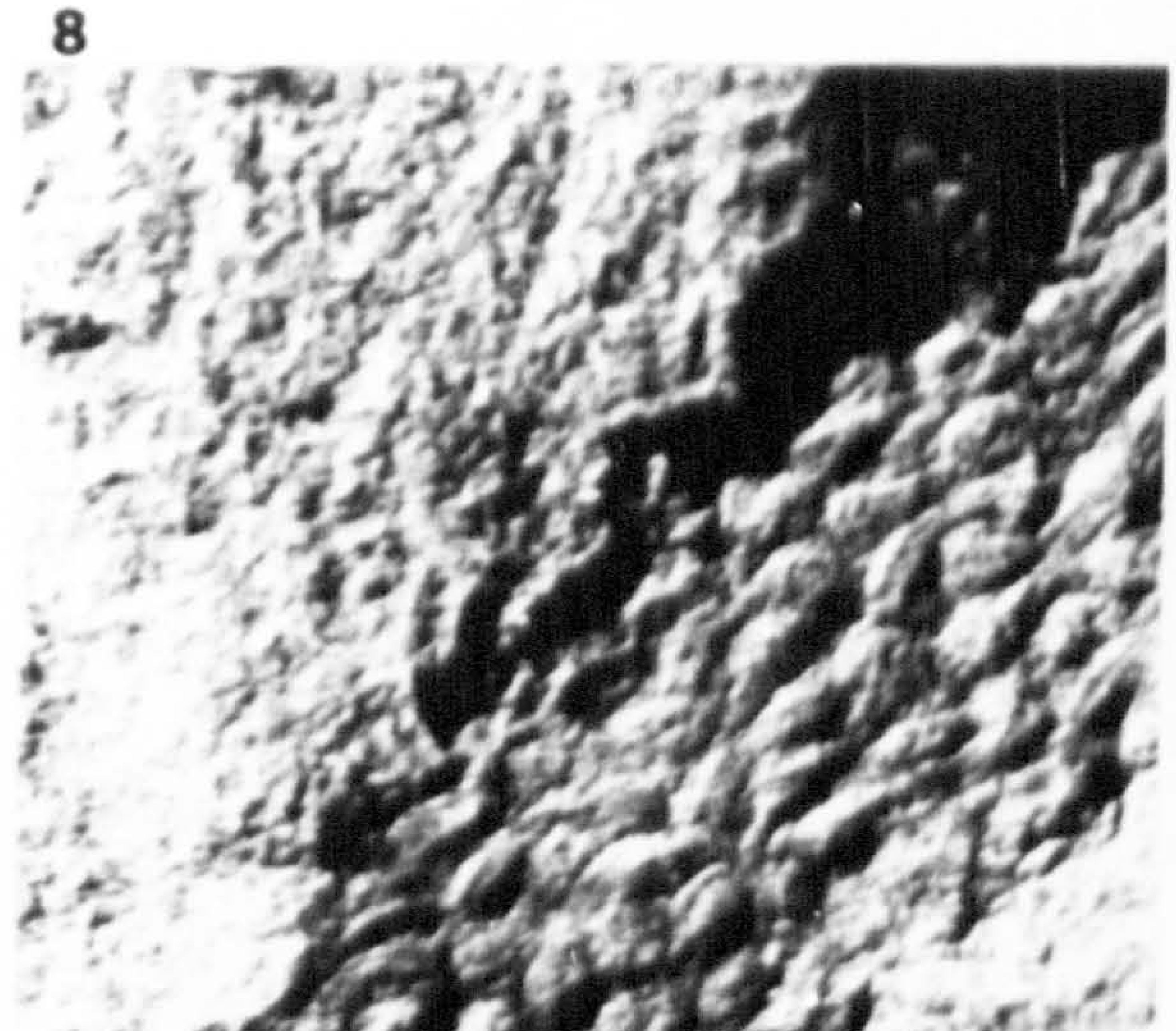
6

cm.

7

cm.

8



cm.

PLATE 3

Plate 3·9 Scanning electron micrograph of latex cast of *Glossopteris angustifolia*. Abaxial surface. Magnification approximately X 40. Stub i.

Specimen Number Z.498.20

Plate 3·10 Scanning electron micrograph of latex cast of *Glossopteris angustifolia*. Abaxial surface. Magnification approximately X 170. Stub i.

Specimen Number Z.498.20

Plate 3·11 Scanning electron micrograph of latex cast of *Glossopteris conspicua*. Abaxial surface. Magnification approximately X 40. Stub j.

Specimen Number Z.498.20

Plate 3·12 Scanning electron micrograph of latex cast of *Glossopteris conspicua*. Abaxial surface. Magnification approximately X 170. Stub j.

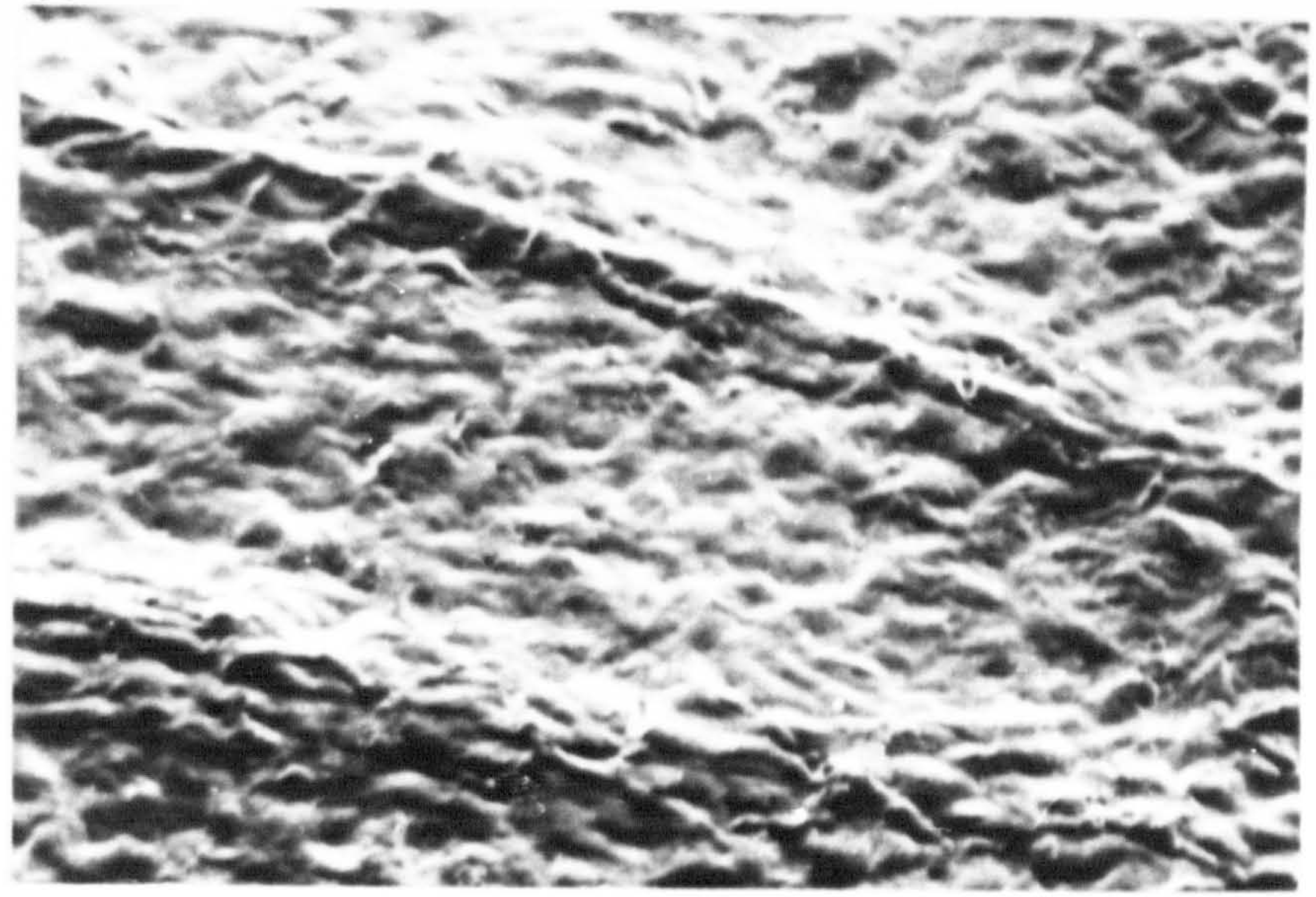
Specimen Number Z.498.20

9

mm

10

0·1 mm.

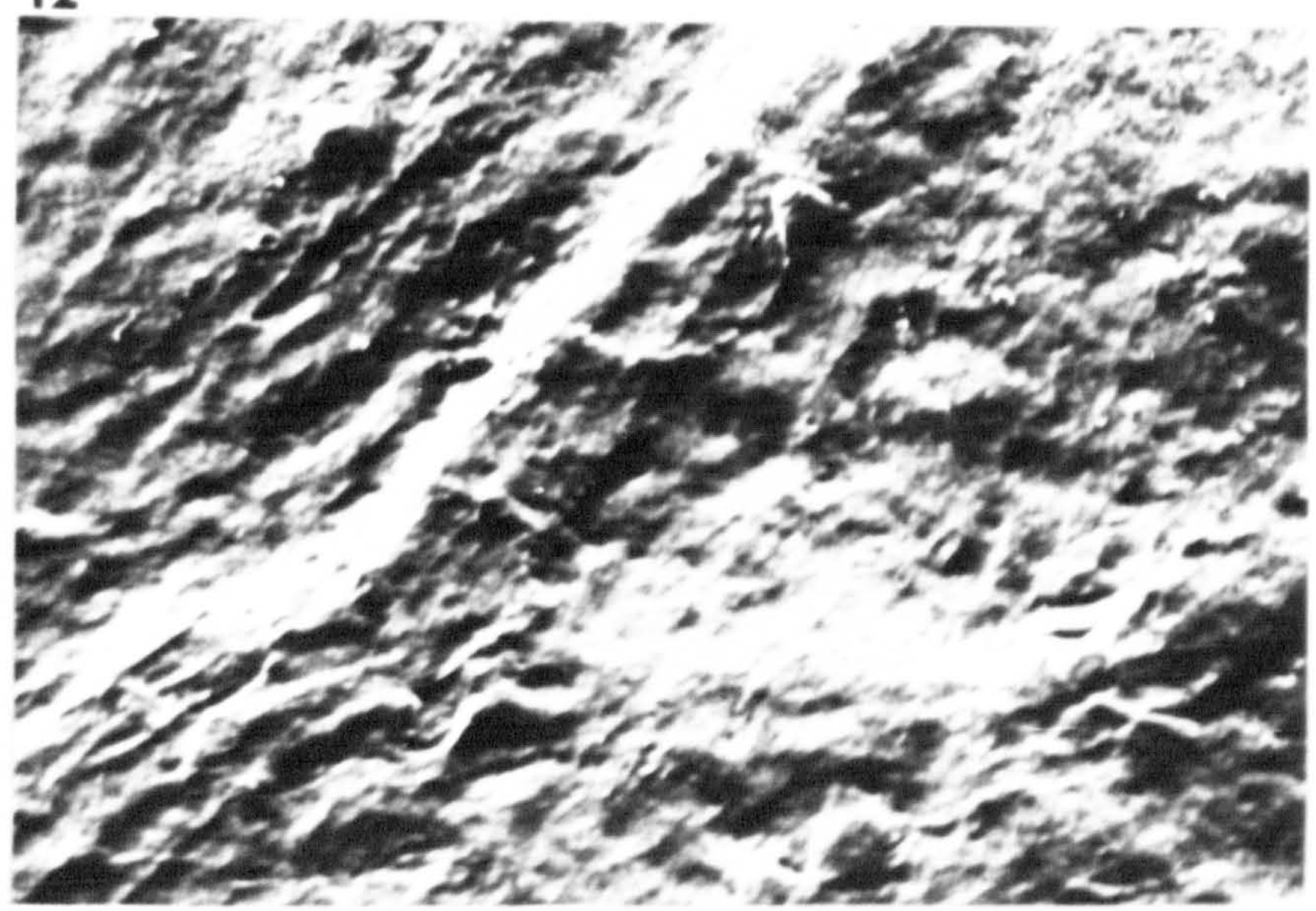


11

mm

12

0·1 mm.



# CHAPTER TWO

# A TRIASSIC FLORA FROM LIVINGSTON ISLAND

# CHAPTER 2

## SUMMARY

A Triassic flora is described from new collections made on Livingston Island in the South Shetlands, Antarctica.

The material consists of over sixty - five hand specimens from three sub - collections and contains at least twelve taxa, including possible bryopsids, sphenopsids, a pteropsid, cycadopsids, coniferopsids and many indeterminate roots, stems and leaves.

Some specimens show a lignitic form of preservation and have in some cases revealed internal structure on sectioning.

The collection has been determined as of probable Ladino - Carnian (upper Mid - lower Upper Triassic) age.

## INTRODUCTION

During the British Antarctic Expedition of 1910 - 1913, Priestley discovered carbonized wood in a boulder on the west side of a glacier now named after him. This was described by Seward (1914) as Antarcticoxylon but later transferred by Walton (1925a) to Rhexoxylon, a characteristic Triassic genus from South Africa.

A Triassic age determination for this wood has been disputed on a number of counts. For example, no Triassic site has ever been found on the west side of Priestley Glacier and Kräusel has questioned Walton's identification. Schopf (1962) has recorded Antarcticoxylon from the Permo - Carboniferous period, although he has also recorded this wood from Lower Triassic deposits (Schopf, 1973).

Plumstead (1962) has described a very poorly preserved Triassic flora from four sites at the head of the Upper Taylor Glacier in the Ross Sea area. Kräusel (1962) described the wood collected from these same deposits.

More recently Townrow (1967) has described three Triassic floras from Allan Nunatak (Victoria Land) and from the Mill and Shackleton Glaciers. These were partly described by Grindley et al. (1964).

Orlando (1968) described a small Triassic flora from Livingston Island in the South Shetlands. A subsequent larger collection was made and this is the material with which this chapter is concerned.

A review of early Mesozoic Antarctic floras was made by Rigby and Schopf (1969) and updated an earlier one made by Plumstead (1963), but this did not include details of the Livingston Island Flora.

# MATERIAL

Livingston Island is the second largest member of the South Shetland Group and lies north-west of the Antarctic Peninsula. It is situated between latitude 62°27′ and 62°48′S. and longitude 59°45′ and 61°15′W. It measures approximately 70 kilometres long by 35 kilometres wide and lies between Snow Island to the West and Greenwich Island to the East, separated from the Antarctic Peninsula by the Bransfield Strait. The South Shetlands form part of the Scotia arc which is a continuous submarine ridge joining South America to Western Antarctica.

Plant material was originally collected for the British Antarctic Survey by G. J. Hobbs in 1959 and described by Orlando (1968). Recently new material was collected by M. R. A. Thomson and J. L. Smellie from the same locality (Williams Point), a small peninsula in the north-west of the island (refer to Text Figure 11).

The Point is largely formed of a columnar jointed basaltic sill, underlain by sub-horizontal well bedded greyish carbonaceous mudstones and fine sandstones.

To the south are one or possibly two coalescing volcanic vents and another cliff exposure of a columnar sill which may well once have been continuous with that of Williams Point proper. Sediments exposed beneath this sill , south of the vent, consist of coarse grained iron sandstones and conglomerates.

Four fossil sites were found and collections totalling over sixty-five hand specimens were made at three of these sites. The best exposure of the mudstone - sandstone fossiliferous sequence is on the west side of the point and immediately north of the vents. Unfortunately it is not accessible from the cliff top and access by sea would probably be dangerous. Refer to Text Figure 12 for the position of the fossil sites.

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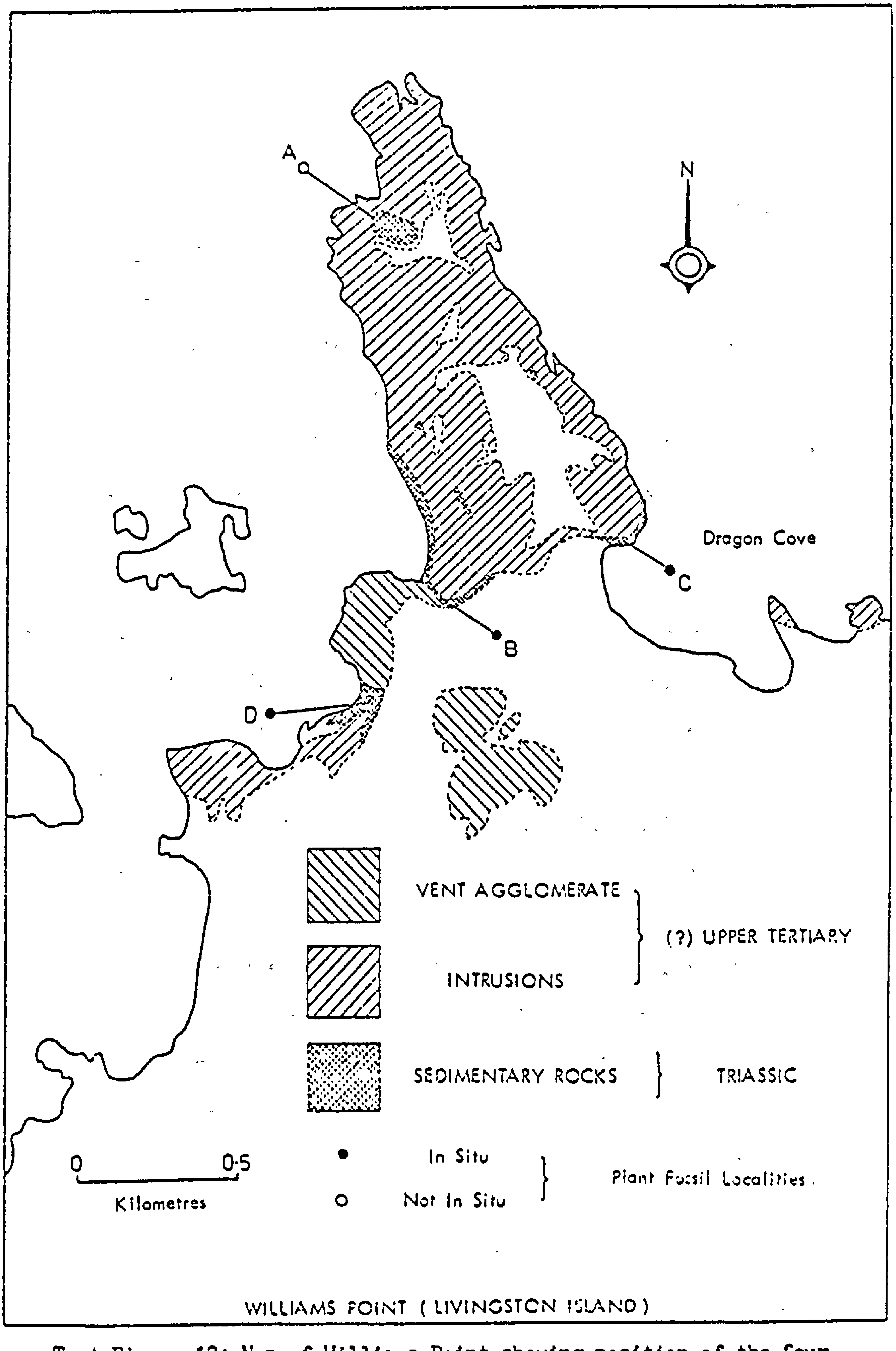
Please refer to original text to see this material.




Text Figure 12: Map of Williams Point showing position of the four fossil sites.

Locality A. Detrital material. (Specimens P.224.17 - P.224.55)

This is one of the best sites and the specimens collected from surface debris form the bulk of the collection.

It is thought that this debris resulted from large squeeze - up structures with the sediments almost pushing through the upper surface of the sill. G. J. Hobbs collected material from this site in 1959 and it was later described by Orlando (1968). This will be referred to as the Hobbs collection to distinguish it from the present collection in subsequent references in this chapter.

Petrology; Carried out by J. L. Smellie who determined the following. P.224.25 - Mudstone - claystone; a very fine grained rock largely composed of indeterminable micro-crystalline matrix with silt sized grains of quartz, feldspar, epidote and carbonaceous matter.

Locality B. In Situ. (Specimen P.224.2 - P.224.15) from surface debris and (Specimen P.224.16 a and b). from in situ.

At this site the sequence has been brought to the surface along a fault marginal to the vent.

Locality C. In Situ. (Specimen P.426.4 - P.426.13).

This is an undisturbed exposure of sub-horizontal mudstones and fine sandstones beneath the sill.

Petrology; J.L. Smellie determined the following. P.426.5: Vitric tuff, a volcaniclastic rock formed of colourless fragments of flattened pumice in an abundant yellow - brown matrix. P.426.8: Coarse muddy siltstone. Rather muddy rock in which the individual constituents are difficult to distinguish. It contains numerous carbonaceous smudges and possibly poorly preserved spores.

Locality D. In Situ material.

Carbonized log and twig moulds were seen but none were collected.

It is clear that the Williams Point plant beds were deposited close to an area of volcanic activity. The majority of the specimens are preserved as black compressions (only a few impressions are found) and are preserved in a light buff coloured matrix. Some specimens from localities A and C were preserved as partial petrifactions (in a lignitic form) and this permitted anatomical details to be observed in a few of the taxa.

The first small collection from Williams Point made by Hobbs in 1959 and described by Orlando (1968) was determined as Lower - Middle Triassic and is shown in the stratigraphy of Livingston Island in Table 5.

TABLE 5

STRATIGRAPHY OF LIVINGSTON ISLAND (after Hobbs, 1968)

| | |
|---|---|
| RECENT | Glacial deposits<br>Raised beaches |
| PLIOCENE<br>MIOCENE<br>OLIGOCENE | Williams Point conglomerate<br>Dykes (Younger Volcanic Group), andesitic tuffs & lavas with conglomerates & sandstones |
| U. CRETACEOUS/E. TERTIARY | Andean Intrusive Suite |
| U. CRETACEOUS (Campanian)<br>L. CRETACEOUS (Aptian) | |
| UPPER JURASSIC<br>MIDDLE JURASSIC | Older Volcanic Group |
| TRIASSIC | * Plant bearing boulders within Younger Volcanic Gp. |
| CARBONIFEROUS ? | Miers Bluff Series |
| EARLY PALAEOZOIC | |
| PRECAMBRIAN | False Bay Schists |

* Thomson and Smellie could find no evidence that this loose material came from weathered boulders within a 'conglomerate' (the latter being the vent agglomerate which also contains rounded boulders), as stated by Hobbs.

## SYSTEMATIC DESCRIPTION OF THE FLORA

### BRYOPSIDA ?

Form - Genus Thallites Walton 1925

This form - genus was instituted by Walton (after a suggestion by Kidston) to include fossils in which the plant body is of a thalloid form, as may be found in the Algae, Bryophyta or sometimes in higher groups but possessing no characters by which they may be assigned to any one of the groups to the exclusion of all the others (Walton, 1925b).

### Thallites (type a)

(Plate 4:13 and 14, Text Figure 13:A and C)

Several dichotomously branched thallose type plants were identified on a single rock fragment. These remains measured between 3 and 4 millimetres wide and possessed up to two complete dichotomies. A rather indistinct midrib of approximately 1 millimetre in width is present.

By polishing the edge of the rock fragment vertical sections of the thallus were obtained and provided additional information (see Text Figure 13:C). The midrib measured up to 93µm thick and contrasted with the much thinner lamina which measured no more than 7µm thick. Unfortunately, neither pores nor remains of rhizoids could be identified with any certainty.

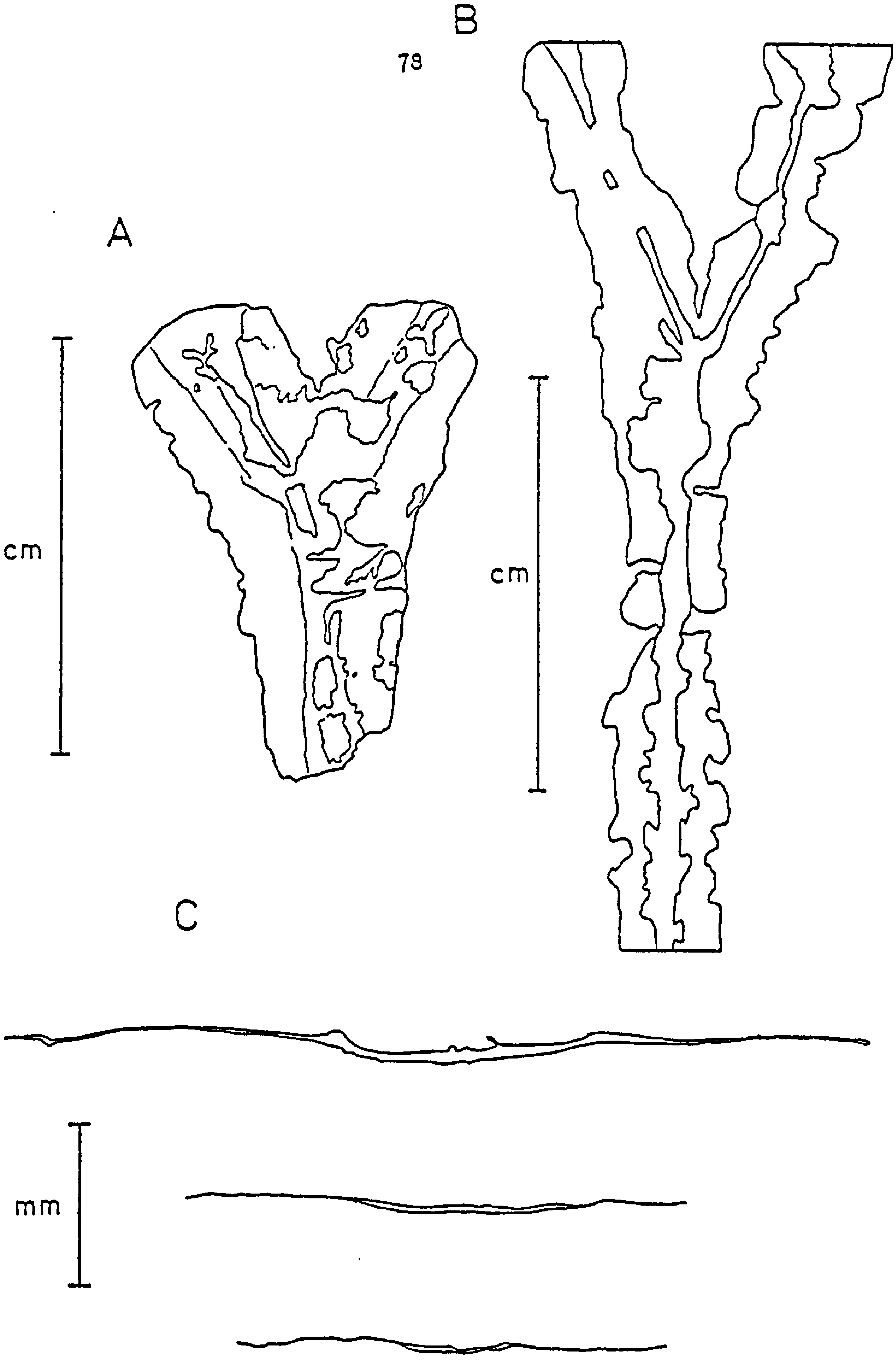
### Thallites (type b)

(Plate 4:15, Text Figure 13:B)

A single, small specimen of a thallose type plant occurs on the reverse side of the same rock fragment.

The specimen measures 0·2 centimetres wide by up to 2·2 centimetres long and exhibits a single dichotomy.

In contrast to type a, the midrib is far more prominent and in the lower half of the specimen, apparent bumps occur along the midrib




Text Figure 13: A. <u>Thallites</u> sp. (type a). 1·15cm long x 3·3mm wide. Specimen Number P.224.21

B. <u>Thallites</u> sp. (type b). 2·2cm long x 2mm wide. Specimen Number P.224.21

C. <u>Thallites</u> sp. (type a). Sections.

(i) 5·28mm wide x 7·0μm - 97μm thick. Slide Number 2 Specimen Number P.224.21

(ii) 3·4mm wide x 7·13μm - 53·5μm thick. Slide Number 1. Specimen Number P.224.21

(iii) 2·64mm wide x 3·56μm - 28·5μm thick. Slide Number 1. Specimen Number P.224.21

| SPECIES | REFERENCE | THALLUS WIDTH | MIDRIB WIDTH | DICHOTOMY | SHAPE |
|---|---|---|---|---|---|
| *Thallites blairmorensis* | (Berry) Lundblad (1954) | 6 – 10mm. | – | Equal 35°–45° | Undulate, not lobed |
| " *dichopleurus* | DiMichele & Phillips (1976) | up to 8·1mm. | 0·36 – 0·5mm. | Unequal 60° | Undulate and lobed |
| " *erectus* | Leckenby (1864), Walton (1925b) | 3·6mm. | 1·4mm.? | Unequal 30°–45° | Not undulate nor lobed |
| " *lichenoides* | (Matthew) Lundblad (1954) | – | – | Unequal – | Radial growth pattern |
| " *marchantiaeformis* | Teixeira (1948) | 5mm. | absent | Equal 30° | Margin lobed |
| " *polydichotomous* | Pyrnada (1938) | 5 – 6mm. | absent | Equal 30°–50° | Margin smooth |
| " *sewardii* | (Berry) Lundblad (1954) | 2 – 3mm. | – | Equal 35°–45° | Undulate, not lobed |
| " *uralensis* | Kryshtofovich & Pyrnada (1933) | 2·8 – 3·75mm. | 1·1mm. | Equal 45° | Constricts after dichot. |
| " *wardii* | Knowlton (1894) | 6mm. | 0·25mm. | Unequal – | Lobed, not undulate |
| " *willsii* | Walton (1949) | up to 1·4mm. | absent | – | – |
| " *yabei* | (Kryshtofovich) Harris (1942) | 12mm. | 1mm. | Equal – | Undulate, not lobed |
| " *yukonensis* | Hollick (1930) | 5·0mm. | 0·8 – 1mm. | indistinct | scaly, air chambers? |
| " *zeilleri* | (Seward) Harris (1942) | – | 1mm.+ | – | – |
| " sp. A | Anderson (1976) | 5·7mm. | 1 – 2mm. | – | Not undulate nor lobed |
| " sp. | Jain & Delevoryas (1967) | 1mm. | – | – | Outline indistinct |
| " sp. | Seward (1894) | 3mm. | 0·75mm. | – | – |

Table 6. Possible comparisons with *Thallites* sp.

and the lamina appears to break up into what could be separate leaflets. This may of course be the result of incomplete preservation and not an original feature. Once again neither pores nor rhizoids were identified with any certainty.

Comparisons with other taxa included in the form genus Thallites are shown in Table 6. None of the specimens compares exactly with the material from Livingston Island, but Thallites sewardii, Thallites uralensis and Thallites sp. of Seward have some similarities with the present Thallites sp. a.

Thallites sewardii is slightly smaller in size and no mention of a midrib was given in the diagnosis. The frond divides equally at an angle of between 35 - 45 degrees and although the thallus is not lobed, it is slightly undulated, a character not seen in the present material.

Thallites uralensis is very similar to Thallites sp. a. in both size, possession of a midrib and pattern of branching (ie. equal dichotomies at an angle of 45 degrees). It is stated that the thallus constricts sharply after branching, a feature not seen in the present material. In Plate 4:14 the thallus of species a. appears to constrict after branching but this is only an illusion due to the matrix covering some of the thallus.

Thallites sp. (Seward, 1894) compares in respect to both size and the possession of a midrib, but unfortunately the diagnosis is incomplete and prevents further comparisons.

No comparisons can be made with Thallites sp. b. from Table 6.

Thallites sp. a. can be compared with living such as Riccardia (Jungermanniales) or even Pellia (Metzgeriales) and Thallites sp. b. with Pallavicinia and Moerckia (Jungermanniales), particularly if the small bumps near the midrib were interpreted as possible reproductive organs such as involucres.

## SPHENOPSIDA

### Genus Equisetites Sternberg 1833

Erected by Sternberg to include fossil stems bearing a close resemblance to recent species of *Equisetum*. The species may be of varying size but are characterized by fairly small scale-like leaf sheaths which are often closely adpressed to the main stem. The free acuminate teeth are fused into a continuous collar.

In compressed specimens, nodal diaphragms and leaf sheaths may be found in the surrounding matrix or displaced and lying on top of the axis.

### *Equisetites* sp.

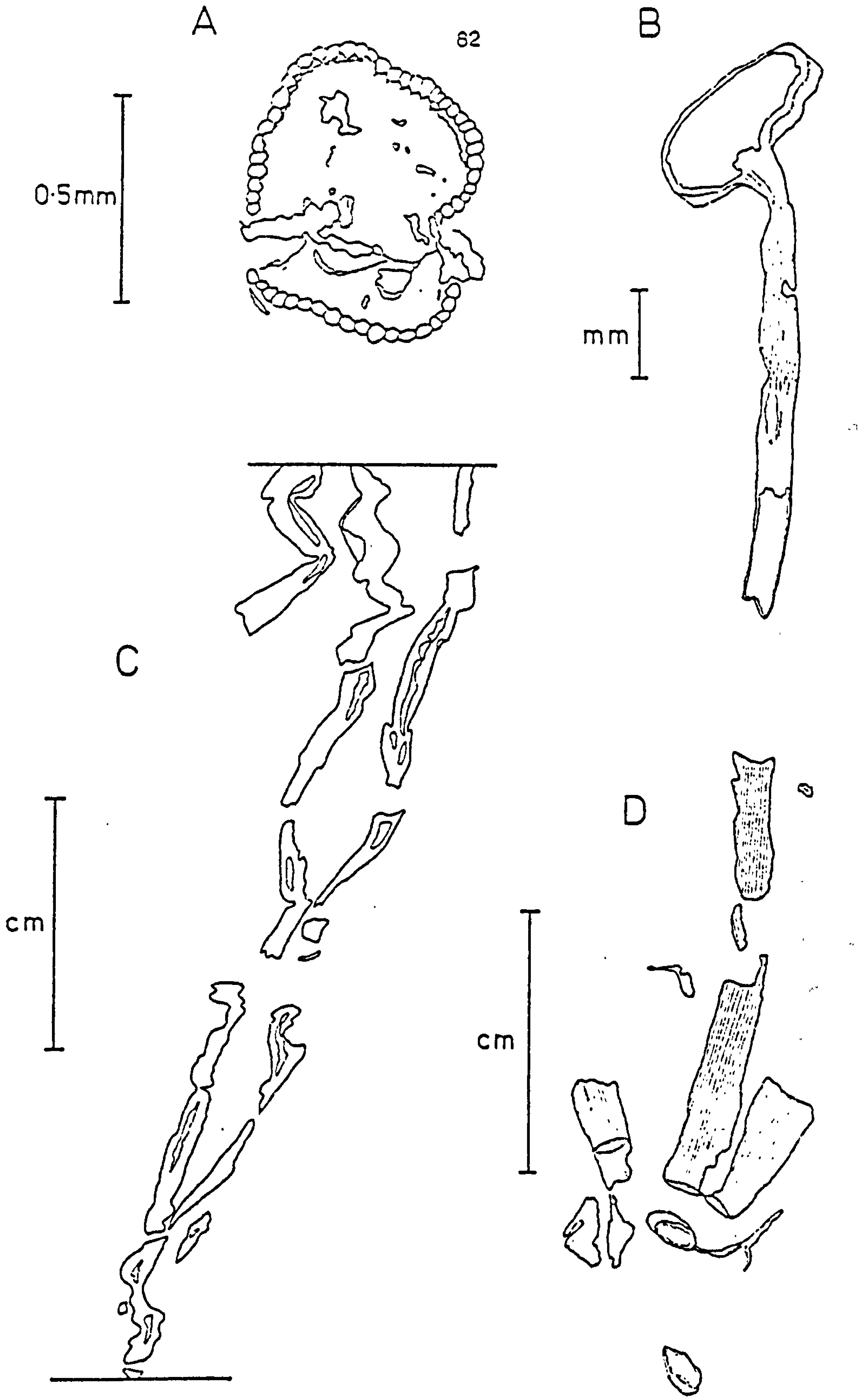
(Plate 5:17 - 20, Text Figure 14, 15 and 16:A & B)

Large numbers of fragmented axes, many of these in situ (ie. preserved vertical to the bedding plane) were found in the collection. The axes measure from 0·5 - 2·5 millimetres in diameter, possess apparent internode lengths of between 4 - 10 millimetres and specimens up to 4·6 centimetres have been recorded.

In nearly all cases, the axes are hollow, tubular structures composed of a single or rarely double layer of cells and this can be observed in both transverse and longitudinal sections.

Plate 5:17 illustrates a low power view of the polished surface of a hand specimen containing a large number of these axes and was photographed under xylol to improve the contrast. Plates 5:18, 5:19 and Text Figure 14:A are high powered photographs and a camera lucida drawing of the cellular detail visible with increased magnification.

In fractures which have occured vertical to the bedding plane, specimens can be seen as meandering, distorted stems often broken or bent at the nodes (refer to Plate 5:20 and Text Figure 14:C).




Text Figure 14: A. Equisetites sp. 0·70mm x 0·6mm in diameter. Slide Number 6. Specimen Number P.224.25

B. Equisetites sp. 6·5mm long. Specimen Number P.426.13

C. Equisetites sp; 3·9cm long x 1·25mm wide. Specimen Number P.426.13

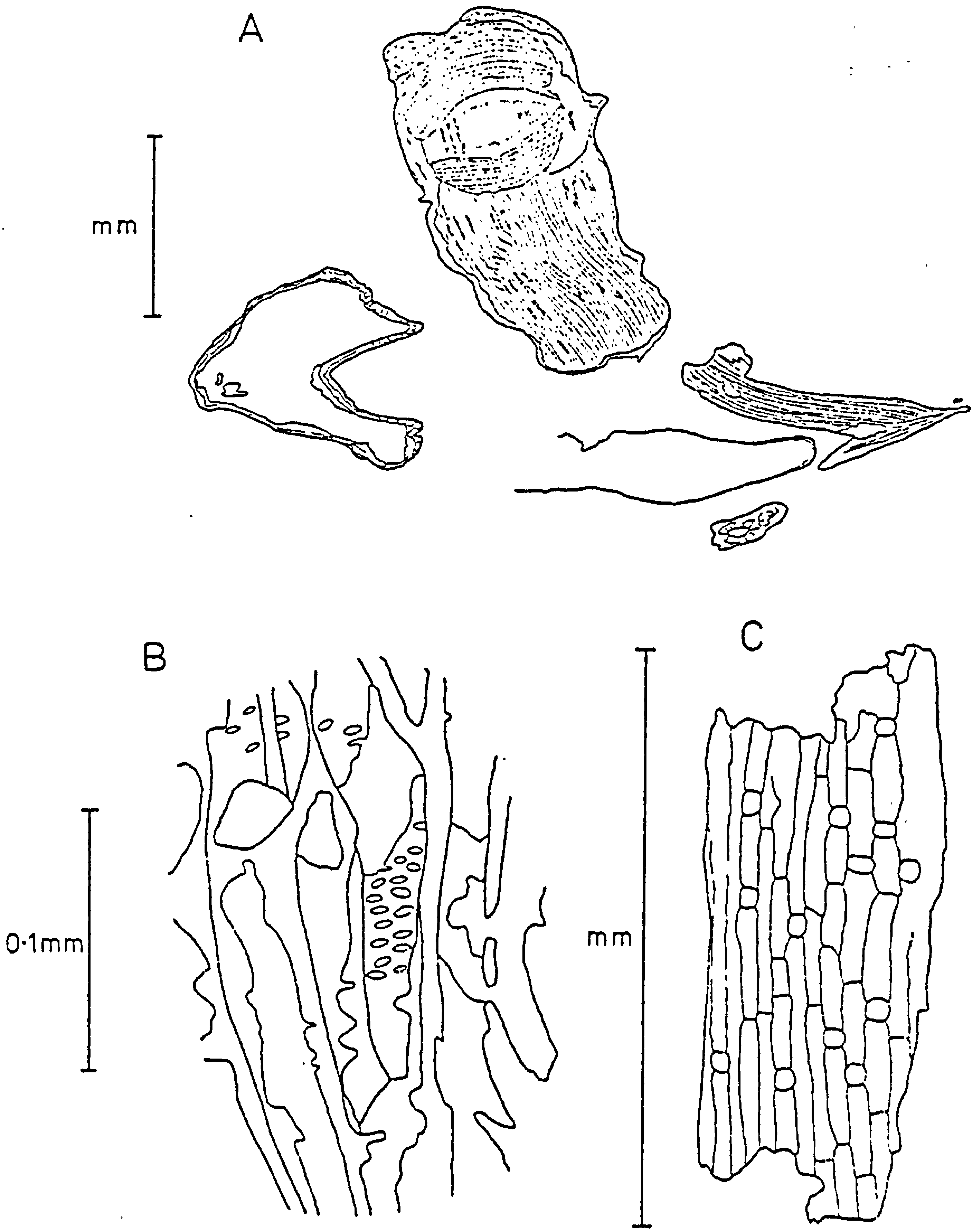
D. Equisetites sp. 2cm long x 1·75 - 2·5mm wide. Specimen Number P.426.13

Branching appears to be uncommon and only a single specimen has been found which may represent the remains of nodal branching (refer to Text Figure 14:D).

In general, the plant is preserved in situ as diminutive, solitary axes exhibiting very little branching and without apparent leaf sheaths. This suggests that these specimens may be immature, or if mature, grew to only a small size and branched rarely. In either case the leaf whorl must have been extremely delicate to account for its lack of preservation.

Another possibility is that the axes represent the sub-terranean and rhizomatous portion of the plant. This idea is supported by the identification of root bearing axes preserved parallel to the bedding plane (refer to Text Figure 14:B and 16:A and B). In Text Figure 14:B an axis preserved <u>in situ</u> possesses a smaller branch which runs parallel to the bedding plane. In Text Figure 16:B a similar sized axis, found in the Hobbs collection, bears lateral roots up to 0·4 millimetres long. Sections were made of some of these smaller axes and these revealed anatomical detail on examination (see Text Figure 16:A). The stele appears to be diarch and shows secondary thickening ? and most of the outer tissue, apart from the epidermis, has not been preserved. The smaller of the two axes seems to have a very small stele but details are not certain.

From the same series of peel sections, details of a larger axis were obtained. The main axis appeared laterally compressed (see Text Figure 15:A) and revealed a similar diarch stele pattern, as was observed in the section of the rhizome. Owing to the obliqueness of the section and distortion of the specimen it was possible to observe the wood in longitudinal section and in a few of the tracheids, the pitting was preserved (see Text Figure 15:B). The tracheid is 150µm long with




Text Figure 15: A. Equisetites sp. oblique section. 2·25mm. long x 1·0mm wide. Slide Number 8. Specimen Number P.426.5

B. Equisetites sp. tracheid. 150um long. Pits 2·85μm x 6·25μm. Slide Number 8. Specimen Number P.426.5

C. Equisetites sp. epidermis impression. 1·0 long Specimen Number P.426.13

alternate, elliptical pits measuring 2·85µm by 6·25µm in diameter.

In Text Figure 15:C an impression of the epidermal pattern of one of the smaller axes is shown. It measures 1·0 millimetre long by 0·42 millimetres wide and reveals smaller, round shaped cells among larger, elongate cell impressions. The smaller cells could be stomata or the remains of root bases. Although on a somewhat larger scale, it compares with the cuticle of *Equisetites* sp. figured by Seward (1912).

Harris (1931) in delimiting species of *Equisetites* uses five characters, these being the size and number of leaf-teeth in a whorl; the size of the internodes; the size of the stems and cuticle evidence.

As only two or possibly three of these characters are available for the present species, superficial comparisons must be made until further evidence is obtained.

Tralau (1977) states that at present there are at least one hundred recognized species of *Equisetites* known since Permian times. Comparisons have been made with some of the better characterized species, including those desribed from the southern hemisphere (refer to Table 7).

From the list, *Equisetites burchardti*, *Equisetites fertilis* and *Equisetites minuta* would appear to have the most in common with the material from Livingston Island. *Equisetites burchardti* has axes 1·5 - 3·0 millimetres wide but unfortunately the length of internode was not stated.

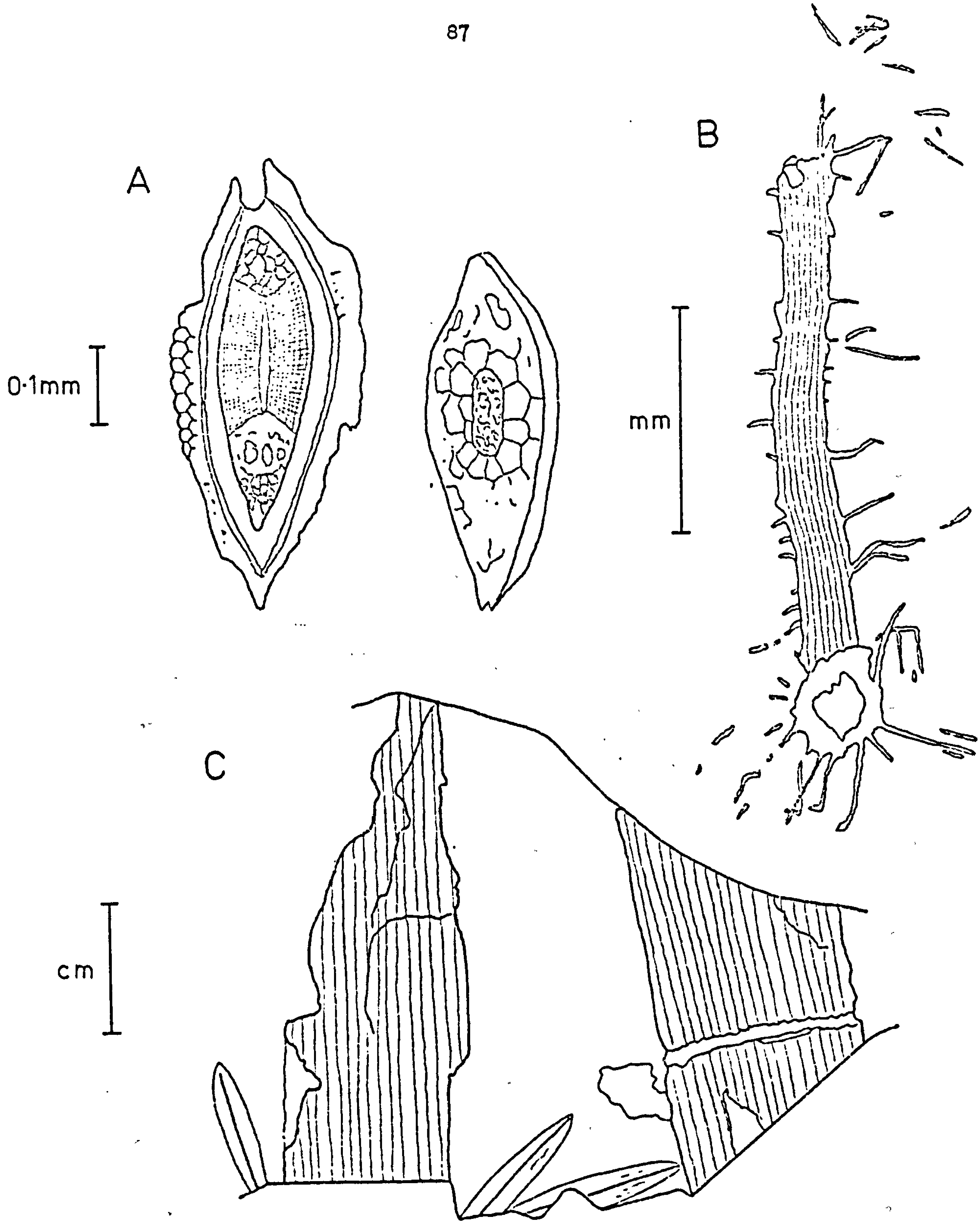
*Equisetites fertilis* has axes measuring 1 - 10 millimetres wide with an internode length of 4 millimetres and so must have attained a much larger size than the present material.

*Equisetites minuta* has axes measuring 1·5 - 3·0 millimetres wide, but as before, internode length was not given.

In view of the fact that not all of the characters of this *Equisetites* sp. are available, it would be unwise to assign the material to a particular species (this would be impossible in two of the cases due also to the fact of incomplete diagnoses).

| SPECIES | REFERENCE | STEM WIDTH | INTERNODE LENGTH | NUMBER OF LEAVES | LENGTH OF LEAVES | AGE |
|---|---|---|---|---|---|---|
| Equisetites approximatus | Du Toit (1927) | 2·5 - 30mm. | less than 25mm. | 15 - 35 | 5mm. | Jurassic |
| " arenaceous | Seward (1900) | 40 - 120mm. | - | 110 - 120 | - | " |
| " beani | Seward (1900) | 20 - 110mm. | 2 - 60mm. | numerous | - | " |
| " burchardti | Seward (1900) | 1·5 - 3mm. | - | 5 - 6 | - | " |
| " columnaris | Harris (1945) | 15 - 60mm. | - | 30 - 80 | 2 - 4mm. | " |
| " doratodon | Harris (1931) | 15 - 20mm. | 20 - 60mm. | 16 | 30mm. | " |
| " ferganensis | Seward (1912) | 10 - 30mm. | 30 - 60mm. | - | - | " |
| " fertilis | Jain & Delevoryas (1967) | 1 - 10mm. | 4mm. | 12 | 5mm. | Triassic |
| " fylensis | Tralau (1977) | 4 - 5mm. | 14 - 20mm. | 12 | 3 - 6mm. | Jurassic |
| " grosphodon | Harris (1931) | 15 - 40mm. | 15 - 40mm. | 30 - 40 | 20mm. | " |
| " hollowayi | Edwards (1934) | less than 10mm. | 10 - 30mm. | 10 | - | " |
| " laevis | Harris (1931) | 3·5 - 34mm. | 150mm. | - | 4 - 15mm. | " |
| " lateralis | Harris (1945) | 10 - 30mm. | 30 - 60mm. | 25 - 35 | 10mm. | " |
| " minuta | Arber (1917) | 1·5 - 3mm. | - | 10 | 5mm. | " |
| " munsteri | Harris (1931) | 6 - 28mm. | 30mm. | 12 | 12mm. | " |
| " nicoli | Arber (1917) | 10mm.+ | 30mm.+ | 15 - 20 | 20mm.+ | " |
| " platyodon | Du Toit (1927) | 20mm. | - | 36 | 2mm. | " |
| " rajmahalense | Halle (1913) | 3 - 30mm. | 25mm. | - | - | " |
| " rotiferum | Walkom (1915) | 7 - 11mm. | 17 - 20mm. | 18 | 1 - 10mm. | Triassic |

Table 7. Possible comparisons with Equisetites sp.




Text Figure 16: A. Equisetites sp. Possible section through rhizome. Larger specimen measures 585µm x 287µm in diameter. Slide Number 9. Specimen Number P.426.5

B. Equisetites sp. Rhizome. Measures 2·8mm long. Slide Number 3. Hobbs Specimen Number P.101.14

C. Neocalamites sp. Axes and possible nodal whorl. Axes measure 3·8cm x 1·5cm and 3·1cm x 1·9cm, whorl segments 0·25cm wide x 1·1 – 1·8cm long. Specimen Number P.426.11

## <u>Neocalamites</u> Halle 1908

The genus <u>Neocalamites</u> resembles the genera <u>Calamites</u>, <u>Schizoneura</u> and <u>Phyllotheca</u>. It differs from <u>Calamites</u> in age but is contemporaneous with species of <u>Schizoneura</u> and <u>Phyllotheca</u>.

<u>Neocalamites</u> is characterized by fairly thick stems, leafy slender branches and leaf whorls at the nodes in which the individual leaves (which are free from the base upwards) are longer than the length of the internode section. In specimens lacking leaf whorls, small circular scars mark the point of attachment of the leaves and the prominent ridges on the stems can be seen to be opposite (not alternate) at each node.

### <u>Neocalamites</u> sp.

(Plate 4:16, Text Figure 16:C)

A single compression of two sphenopsid axes, one measuring 3•1 centimetres long by 1•9 centimetres wide and the other measuring 3•8 centimetres long by 1•5 centimetres wide were recognized on a single hand specimen. One specimen possesses a node from which it is seen that the ridges are opposite (continuous) from one internode to the next, although details of the nodal leaf scars are indistinct.

The possible remains of a single leaf whorl are found surrounding the other axis. The three possible segments of the whorl measure 1•1, 1•8 and 1•4 centimetres long and all measure 0•25 centimetres wide and are so arranged in a position around the axis as to give the impression of a diverging leaf sheath. Unfortunately, the node itself was not preserved on this specimen.

The free segments of this possible leaf whorl have a single, central vein running the entire length of the lamina, which is lanceolate in shape.

If these leaves are not associated with the axis, then the specimen could equally well be placed in the genus <u>Paracalamites</u> (Rigby, 1966).

However, from the evidence available from the fragment, it would appear that these leaves may have been attached, indicating that the axes should be included in the genus _Neocalamites_.

_Neocalamites höerensis_ has long internode sections (Du Toit, 1927) and possessed leaf sheaths with free segments measuring 0·1 – 0·25 centimetres wide (Jones and De Jersey, 1947). Although these facts agree well with the present specimens, it cannot be shown beyond doubt that the axis and whorl were in association and it would be better to record the specimens as simply _Neocalamites_ sp.

## PTEROPSIDA

### Marattiales

Genus Asterotheca Presl 1845

Asterotheca is the name given to pecopterid fronds bearing sessile sori made up of four to five sporangia fused at the base into a synangium, but with the distal part free. The sori were commonly arranged in two series along the pinna.

cf. Asterotheca crassa Orlando 1968

(Plates 6:21 and 6:22, Text Figures 17, 18 and 19:A,B,D-F)

Sterile fragments of fronds, comparable to those described by Orlando (1968) from the earlier collection have been recognized in the material.

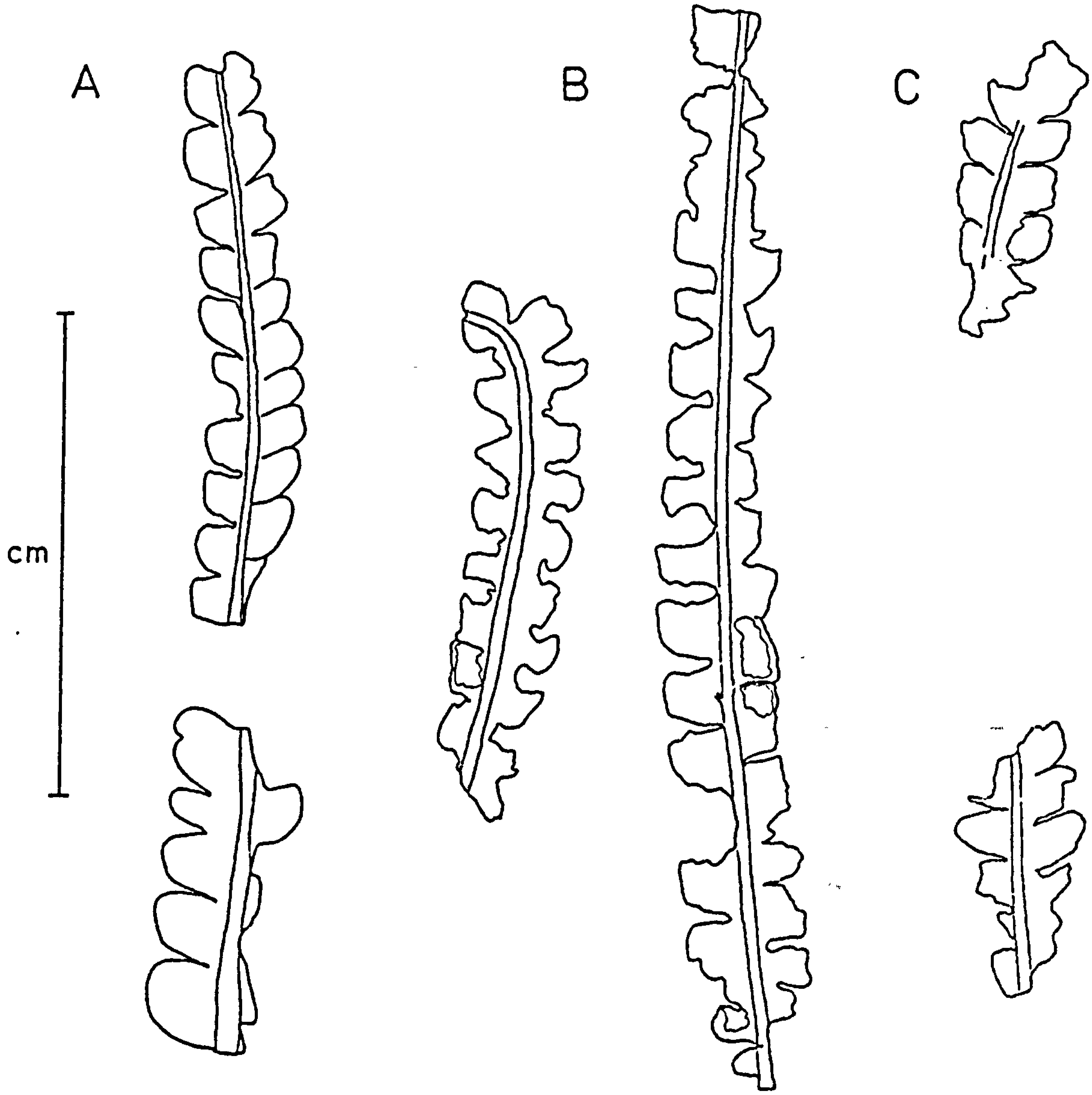
These remains are illustrated in Plate 6:21 and in Text Figures 17 and 18:A. Sections and transfers were made from some of these fronds but little extra information could be obtained owing to the highly compressed nature of the material. Text Figure 18:D illustrates a section made from one of the specimens.

The fronds were of varying lengths between 0·5 and 2·25 centimetres long but were all approximately 2·0 millimetres wide.

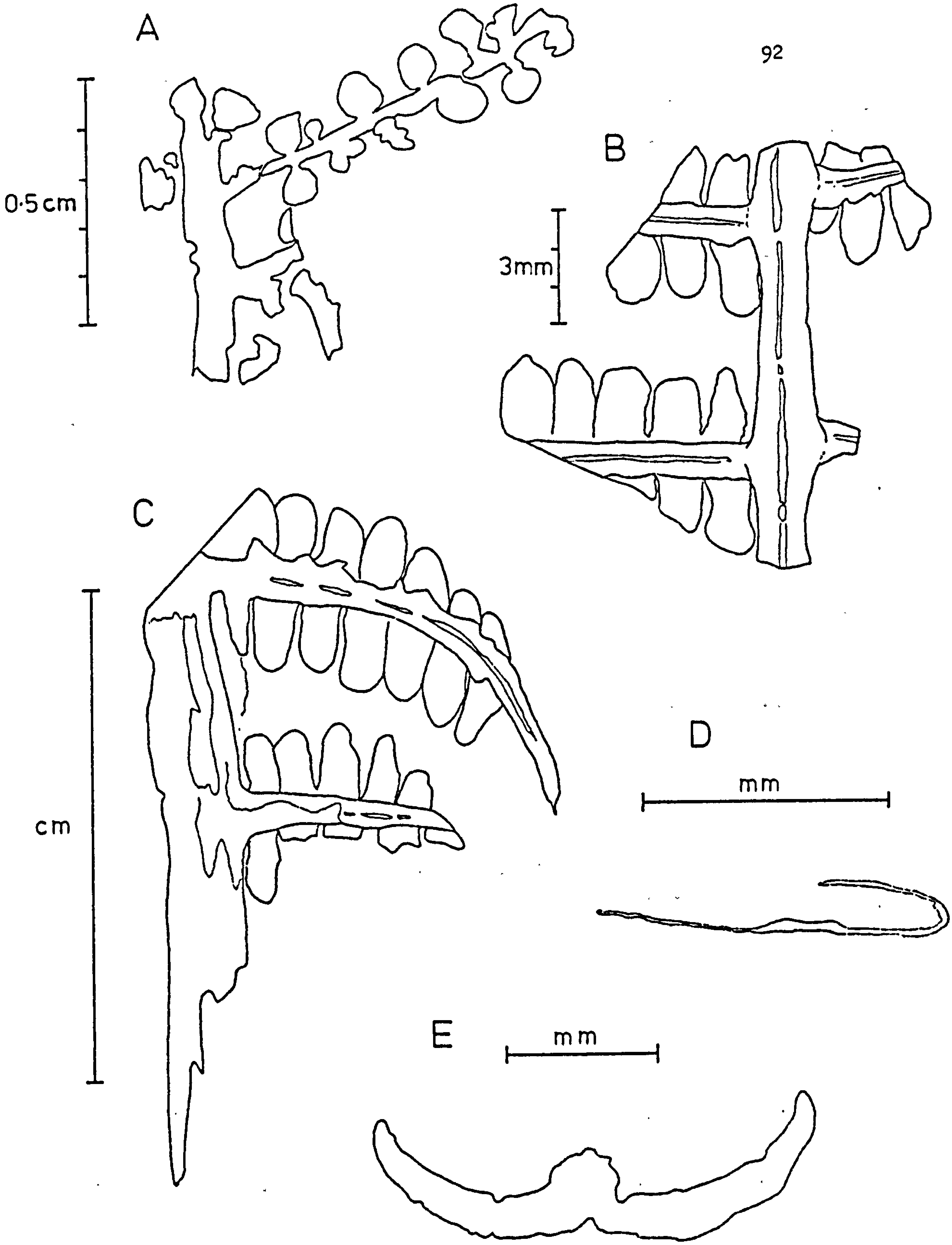
A re-examination of better preserved Asterotheca crassa from the Hobbs collection (ie. that described by Orlando, 1968) was made and has furnished additional information.

Text Figure 18:B and C illustrates the much better state of preservation and a section made of one of the pinnae shows considerably less compression than was observed in the present material (see Text Figure 18:E). This compares with sections made by Townrow (1957).

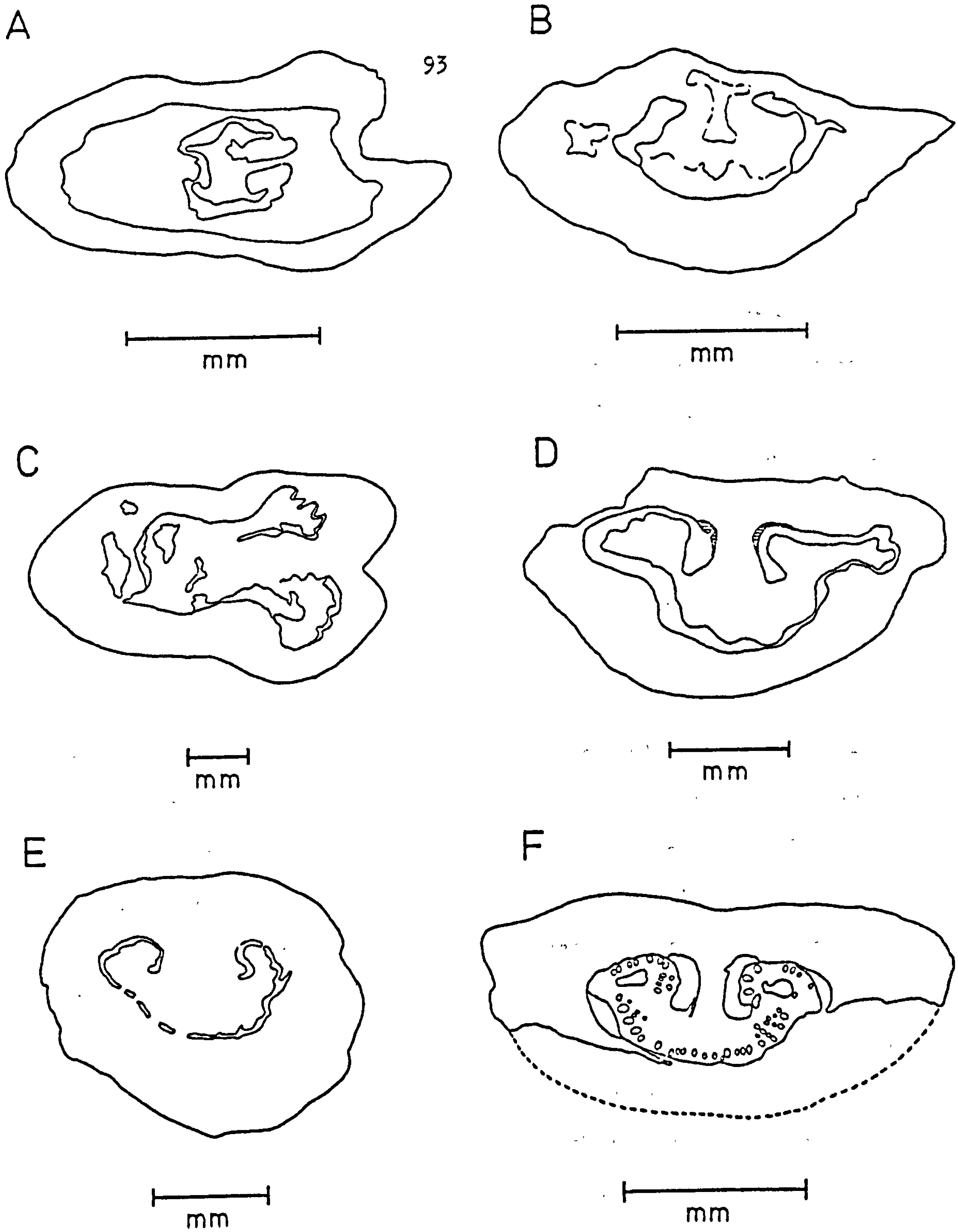
Sections were made from the basal portion of the specimen shown in Text Figure 18:C and also from another specimen which bore Asterotheca




Text Figure 17: A. cf. Asterotheca crassa. 2mm. wide x 1·15 and 6mm. long. Specimen Number P.224.55
B. cf. Asterotheca crassa. 2mm. wide x 1·1cm. and 2·25cm. long. Specimen Number P.224.18
C. cf. Asterotheca crassa. 2mm. wide x 6·5mm. and 5·0mm. long. Specimen Number P.224.18




Text Figure 18: A. cf. Asterotheca crassa. 8mm. wide. Specimen Number P.426.4
B. Asterotheca crassa. 11·3mm. long. Hobbs Specimen Number P.101.
C. Asterotheca crassa. 14mm. long. Hobbs Specimen Number P.101.16
D. cf. Asterotheca crassa. Section. 1·43mm. wide. Slide Number 35 , Specimen Number P.224.40
E. Asterotheca crassa. Section. Slide No.23. Hobbs Specimen Number P.101.8




Text Figure 19: A. Asterotheca crassa. Section. 2·3mm x 1·1mm. in diameter. Slide No. 19. Hobbs Specimen Number P.101.16

B. Asterotheca crassa. Section. 2·3mm. x 1·0mm. in diameter. Slide No.22. Hobbs Specimen Number P.101.15

C. Rachis of Osmundaceae. Orlando(1968). Section is 6mm wide. Hobbs Specimen Number P.101.4

D. cf. Asterotheca crassa. Section. 3·5mm.. x 1.8mm. in diameter. Slide No.33 Specimen Number P.224.48

E. cf. Asterotheca crassa. Section. 2·9mm. x 2·2mm. in diameter. Slide No.31. Specimen Number. P.224.25

F. cf. Asterotheca crassa. Section. 2·50 mm. x 0·8mm. in diameter. Slide No.24. Hobbs Specimen Number P.101.8

_crassa_ type foliage. In both cases, the sections revealed a central C - shaped stelar region. The first section (Text Figure 19:A) appears to have been compressed laterally, whereas the second section (Text Figure 19:B) seems to be less distorted.

It is interesting to compare the first specimen (Text Figure 19:A) with the only section made and figured by Orlando (1968) and referred to as a rachis of Osmundaceae (Text Figure 19:C). Although there is a difference in both size and quality of preservation, the overall similarity of the two sections is very apparent.

Large numbers of non foliage-bearing axes were recognized in both collections, and these were referred to as indeterminate by Orlando (1968). It has been possible to prepare sections from some of these axes and the results are illustrated in Text Figures 19:D - F.

The sections vary in both size and quality but all reveal the same C - shaped trace as seen in the sections of _Asterotheca_ _crassa_. Text Figure 19:F shows one of the best preserved examples (refer to Plate 6:22). It measures 2·50 by 0·8 millimetres in diameter (the largest specimen measured 3·5 by 1·8 millimetres in size) and reveals the position and detail of the xylem within the stele. This specimen compares very well with the section of _Asterotheca crassa_ illustrated in Text Figure 19:B.

It is suggested that the rachis of Osmundaceae described by Orlando (1968) and reproduced here in Text Figure 19:C and many of the axes, which are devoid of foliage but are fairly abundant in both collections should now be included within _Asterotheca_ _crassa_.

# CYCADOPSIDA

## Pteridospermales

### Corystospermaceae

### Genus *Dicroidium* Gothan 1912

*Dicroidium* was first used by Gothan to distinguish southern hemisphere forked *Thinnfeldia* fronds from the more common unforked northern *Thinnfeldia*. This division did not really gain full acceptance until Townrow (1957) demonstrated beyond doubt that *Dicroidium* could be separated from *Thinnfeldia* on several counts, including geographical, stratigraphical, cuticular and morphological distinctions.

These forked leathery leaves are very characteristic of early Mesozoic Gondwana floras.

### *Dicroidium* cf. *lancifolium* (Morris) Gothan

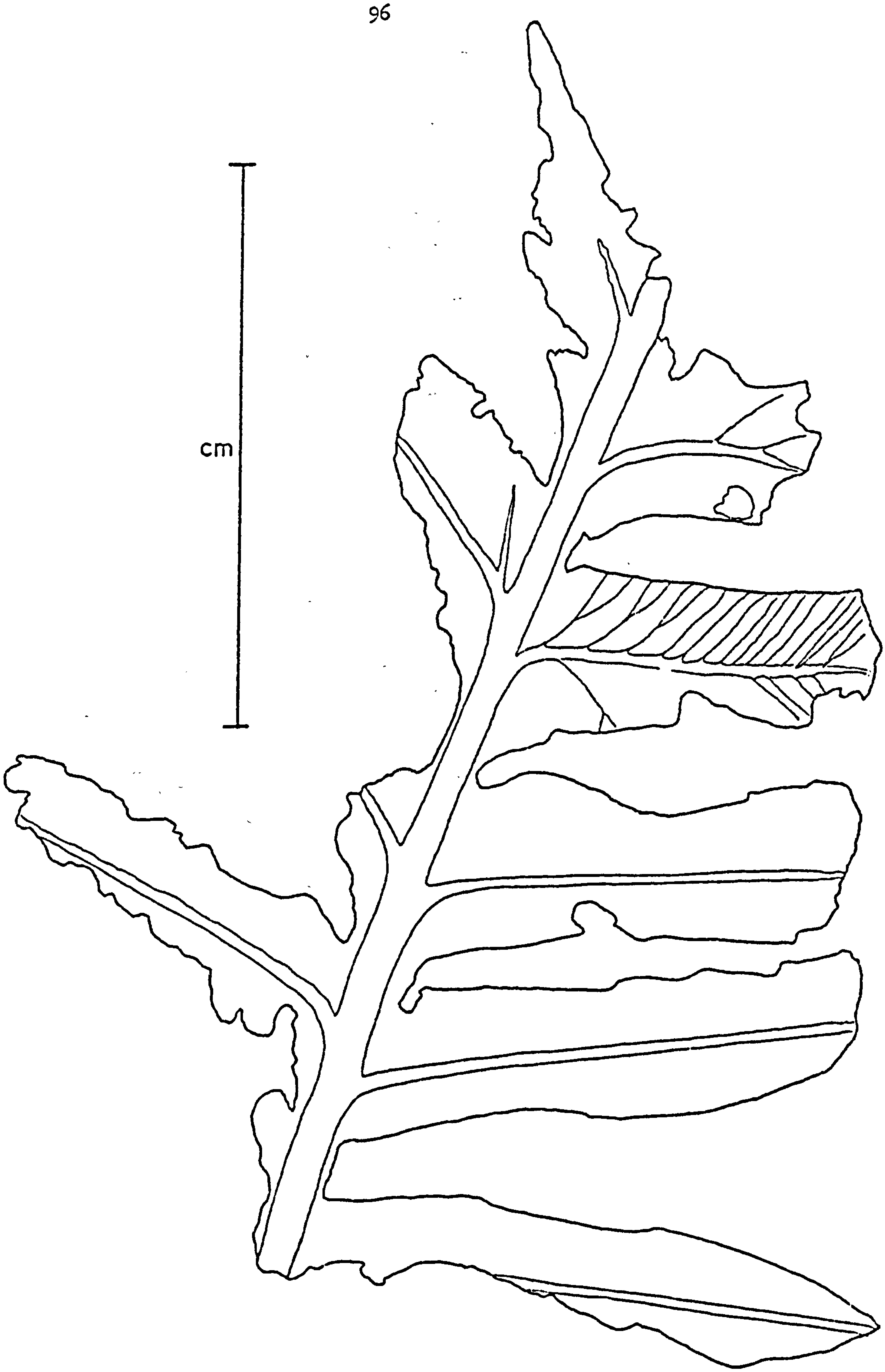
(Plates 6:23 and 6:24, Text Figures 20 and 21)

Two incomplete compressions and the fragments of a third were found on the same hand specimen. The two incomplete fronds measure 2•4 centimetres long by 1•8 centimetres wide and 2•3 centimetres long by 1•25 centimetres wide. The pinnules are arranged alternately, although as the midribs arise from the rachis fairly close together the pinnules appear superficially to be opposite one another.

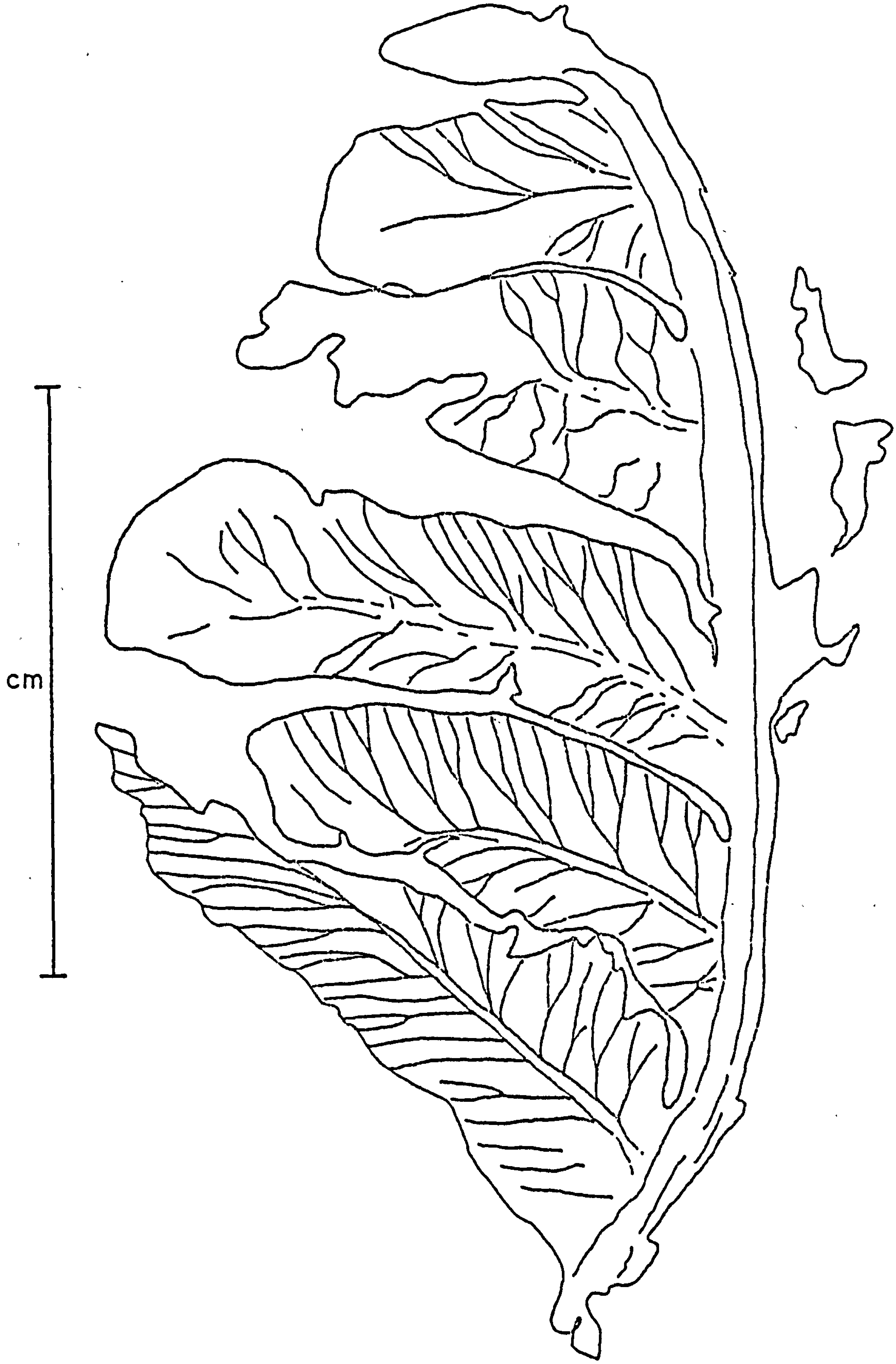
The pinnules measure up to 1•15 centimetres long and up to 3•0 millimetres wide and possess a prominent midrib which gives off secondary veins alternately at an angle of approximately 45 degrees. The secondary veins dichotomize once or twice as they traverse the lamina.

Sections of both rachis and pinnules were attempted but owing to the very small amount of carbon preserved met with little success. Poor preservation also prevented the preparation of cuticles.

Unfortunately as the specimens are incomplete, they do not reveal




Text Figure 20: Dicroidium cf. lancifolium. 2·4cm. long x 1·8cm. wide. Specimen Number P.224.38




Text Figure 21: Dicroidium cf. lancifolium. 2·3cm. long x 1·25cm. wide. Specimen Number P.224.38

the forking of the main axis.

Using gross morphology only, these fronds compare favourably with the genus Dicroidium and more specifically with Dicroidium lancifolium and to a lesser extent with Dicroidium narrabeenense, especially with regard to the length, shape and arrangement of the pinnules.

From the key to species and varieties of Dicroidium put forward by Retallack (1977b), the fronds are identified as Dicroidium lancifolium var. lancifolium.

Du Toit (1927) treated Dicroidium lancifolium as a distinct species whereas Townrow (1957) regarded it as an extreme form of Dicroidium odontopteroides (Morris) Gothan. Lacey (1970 and 1976) has shown there is a size difference between Dicroidium lancifolium and Dicroidium odontopteroides (at least for Rhodesian specimens) and regards them as distinct species.

In this case, although the specimens are fairly small, the pinnules are still larger than the dimensions given in the diagnosis for Dicroidium odontopteroides by Townrow (1957). On this evidence, the specimens are tentatively assigned to Dicroidium lancifolium with the reservation that they may have to be transferred to Dicroidium odontopteroides on a subsequent revision of this species.

Genus Dicroidium (Xylopteris) (Frenguelli) Archangelsky 1968

This genus was originally erected by Saporta under the name of Stenopteris for Pteridosperms of woody habit with pinnate to tripinnate branched fronds or with repeated dichotomous divisions.

The lamina is greatly reduced and the venation consists of a single median vein.

Harris (1932) and Thomas (1933) expressed the opinion that the northern and southern hemisphere species were distinct, based on the absence of a dichotomy in the main axis of the northern species and differences in the cuticles. Frenguelli (1943) grouped these southern stenopterids under the name Xylopteris.

Recently, Archangelsky (1968) has treated Xylopteris as a synonym of Dicroidium and this has been supported by both Townrow (1962) and Bonetti (1966) in earlier publications. Retallack (1977b) however, retains Xylopteris as a distinct genus.

I have adopted the former approach.

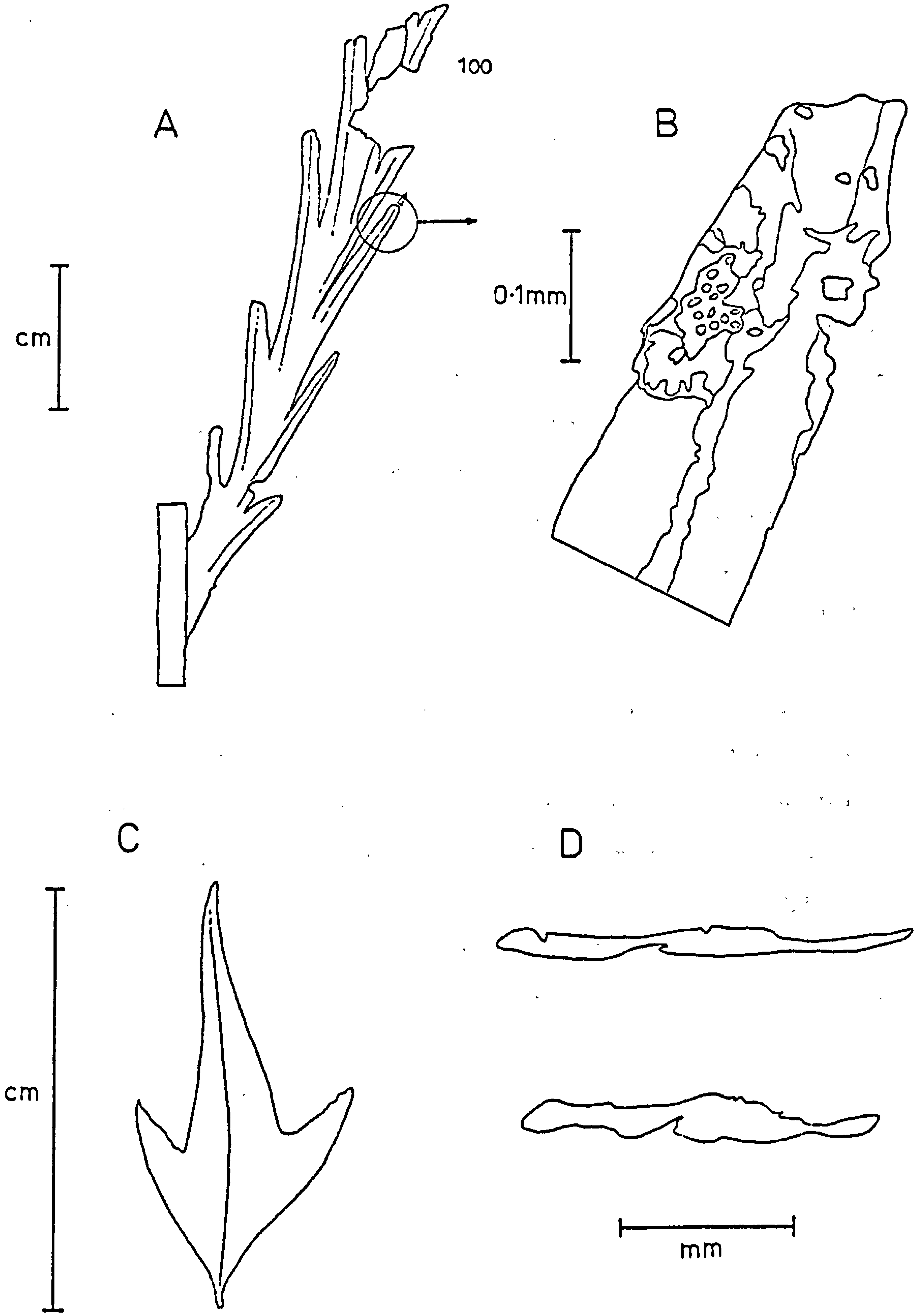
Dicroidium (Xylopteris) cf. spinifolia (Frenguelli) Archangelsky

(Plates 7:25 and 7:26, Text Figure 22:A - D)

Three specimens in total were recognized, plus a few fragments of pinnae which can be included within the genus Dicroidium (Xylopteris).

Two of the specimens are of complete pinnae whereas the third is represented by the pinna apex only and as such has been tentatively assigned to the genus. Since it compares superficially with Dicroidium (Xylopteris) spinifolia it is included in this section.

The first specimen (refer to Plate 7:25 and Text Figures 22:A, B and D) is a slender, bipinnate forking frond measuring 6•5 centimetres long. Each pinna is made up of sub-opposite branching pinnules measuring up to 1•1 centimetres long by 1•3 millimetres wide, with a distinct median vein which persists almost to the apex. The rachis, part of which




Text Figure 22: A. Dicroidium (Xylopteris) cf. spinifolia. 4·75cm. long x 6·5mm. wide. Specimen Number P.224.37
B. Dicroidium (Xylopteris) cf. spinifolia. Pinnule detail of Text Figure 22:A Specimen Number P.224.37
C. cf. Dicroidium (Xylopteris) spinifolia. 1·0cm long x 4·25mm. wide. Specimen Number P.224.9
D. Dicroidium (Xylopteris) cf. spinifolia. Sections from Text Figure 22:A. Pinnule = 2·4mm. wide and rachis = 2·0mm. wide. Slide No. 47. Specimen Number P.224.37

is buried in the matrix, measures 5•3 centimetres long.

Sections of both rachis and pinnule were obtained (see Text Figure 22:D) but owing to poor preservation no additional information could be obtained.

The second specimen (Plate 7:26) would appear to be the remains of a single pinna composed of four alternating pinnules, each showing a distinctive median vein. The vein occupies a quarter to one third the width of the pinnule and measures 1•3 - 2•0 millimetres wide.

The pinnules are borne 1•3 - 1•5 centimetres apart from each other on the pinna and the entire specimen is 4•2 centimetres long.

This specimen differs from the first in that its overall size is larger and the pinnules are spaced further apart.

The third specimen (see Text Figure 22:C) is the remains of what looks like a very small three lobed 'leaf'. It is thought that this may be the remains of the pinna apex, revealing the three terminal pinnules.

This specimen in fact compares very well with respect to size and shape with the pinna apex of Dicroidium (Xylopteris) spinifolia and tripinnata types, as figured in Retallack (1977b).

All of the specimens compare in many respects with Stenopteris spinifolia (now Dicroidium spinifolia) described and figured by Jones and De Jersey (1947) and so have been cautiously assigned to this species.

## Bennettitales

### Williamsoniaceae

### Genus Pterophyllum Brongniart 1828

The name Pterophyllum was first applied by Brongniart to some fronds from the Lias of Hör, named Pterophyllum majus and Pterophyllum minus.

Brongniart defined the Pterophyllum fronds as pinnate, bearing pinnae of almost equal breadth attached by the whole width of the base and with a truncate apex and slender, equal, simple and slightly arched veins.

Confusion often arises when distinguishing between Nilssonia Brongniart 1825 and Pterophyllum. Seward (1917) pointed out that in Nilssonia there is a complete absence of any rachis uncovered by lamina on the upper surface, the veins are simple and segments of unequal breadth. In Pterophyllum the continuity of the lamina is broken by the width of the rachis as the lamina is attached laterally, the veins are often branched and the segments are of equal breadth.

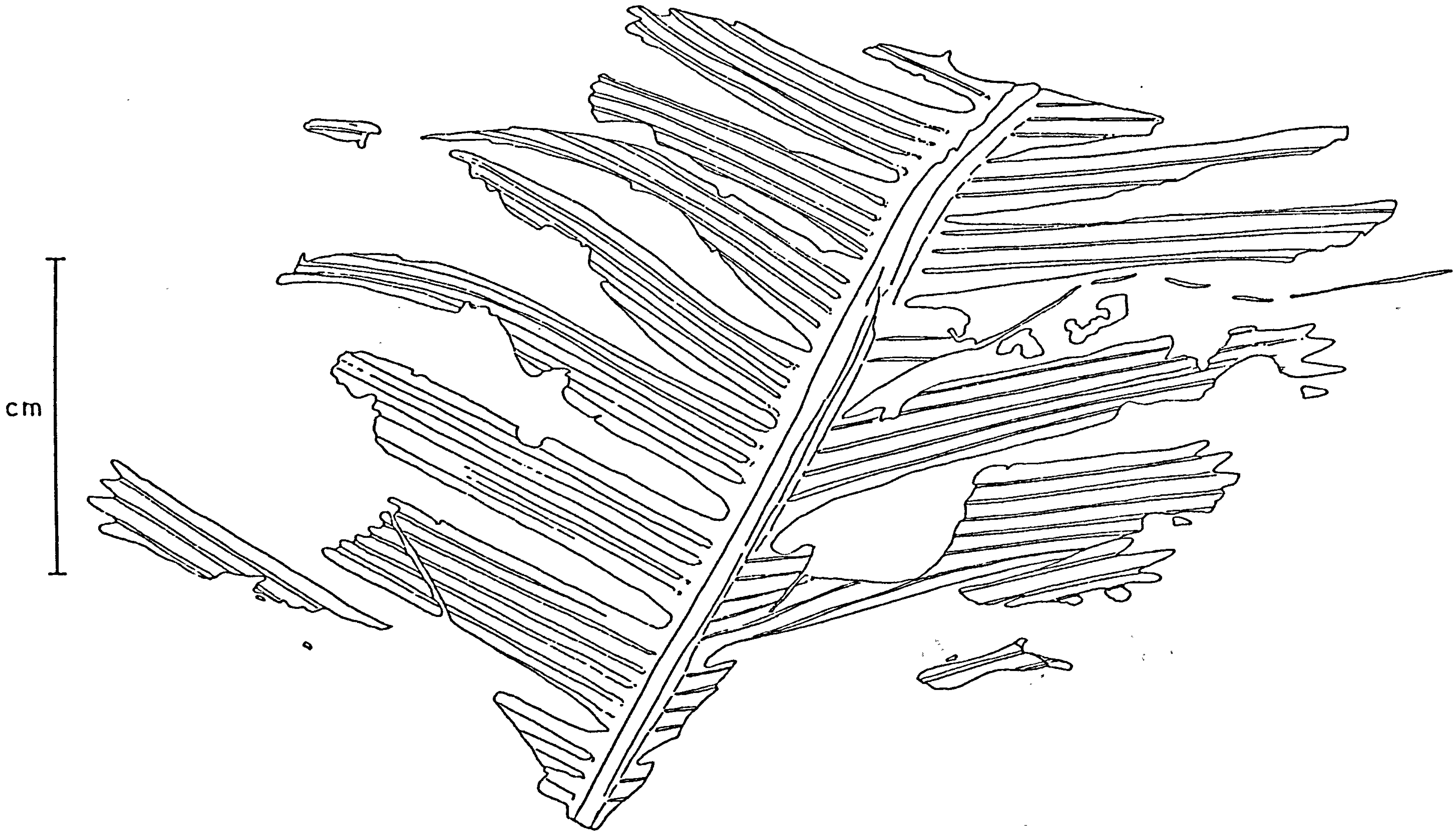
### Pterophyllum dentatum sp. nov.

(Plates 7:27; 8:29; 8:30; 8:31 and 8:32, Text Figures 23, 24 and 25)

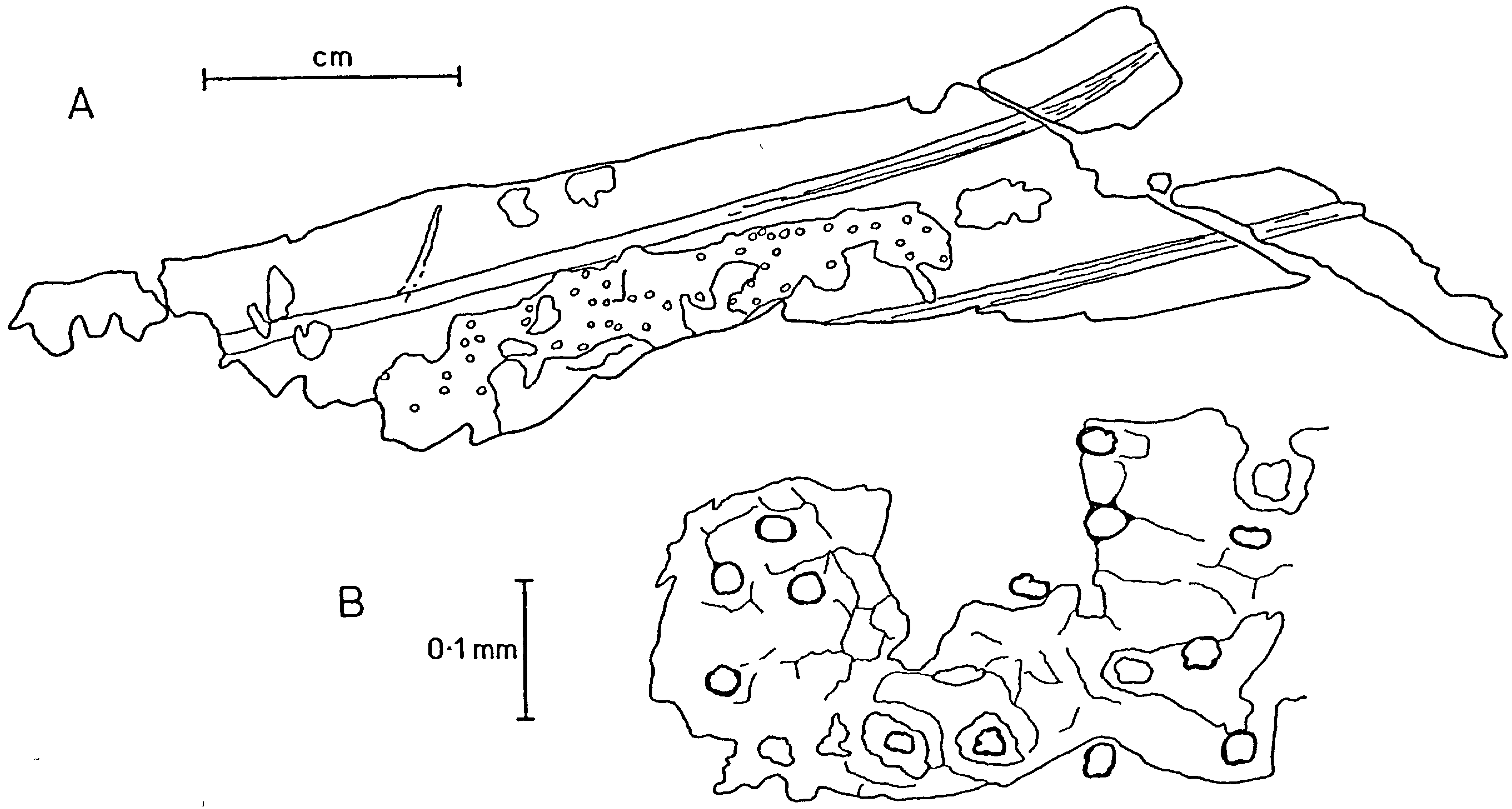
Three specimens, including one part and counterpart, were found in the P.426 sub-collection. The most complete frond measures 3·0 centimetres long by 3·6 centimetres wide and bears opposite to sub-opposite pinnae which each possess four or five veins.

Complete pinnae measure between 1·8 - 2·0 centimetres long by 1·3 - 3·0 millimetres wide and the apex is dissected into four or five finger-like lobes (refer to Plate 7:27 and Text Figure 23).

A high power examination of the pinnae surface using a binocular microscope revealed small structures, which may possibly represent the remains of stoma, pits or hair bases ? (see Text Figure 24:A and B). These structures are seen on the impression of the abaxial surface of




Text Figure 23: Pterophyllum dentatum sp. nov. Frond measures 3·0cm. long x 3·6cm. wide. Specimen Number P.426.5




Text Figure 24: A. Pterophyllum dentatum sp. nov. Pinna. 6mm. long. Specimen Number P.426.5
B. Pterophyllum dentatum sp. nov. Pinna surface detail. Specimen Number P.426.5

pinna, exposed where the compressed carbon has chipped or been weathered off. The structures are preserved as small protuberances and are occasionally seen in loose rows between and parallel to the veins of the pinna. They range in size from 40µm - 53µm long by 34µm - 53µm wide and are spaced apart from one another one half to three times their own size.

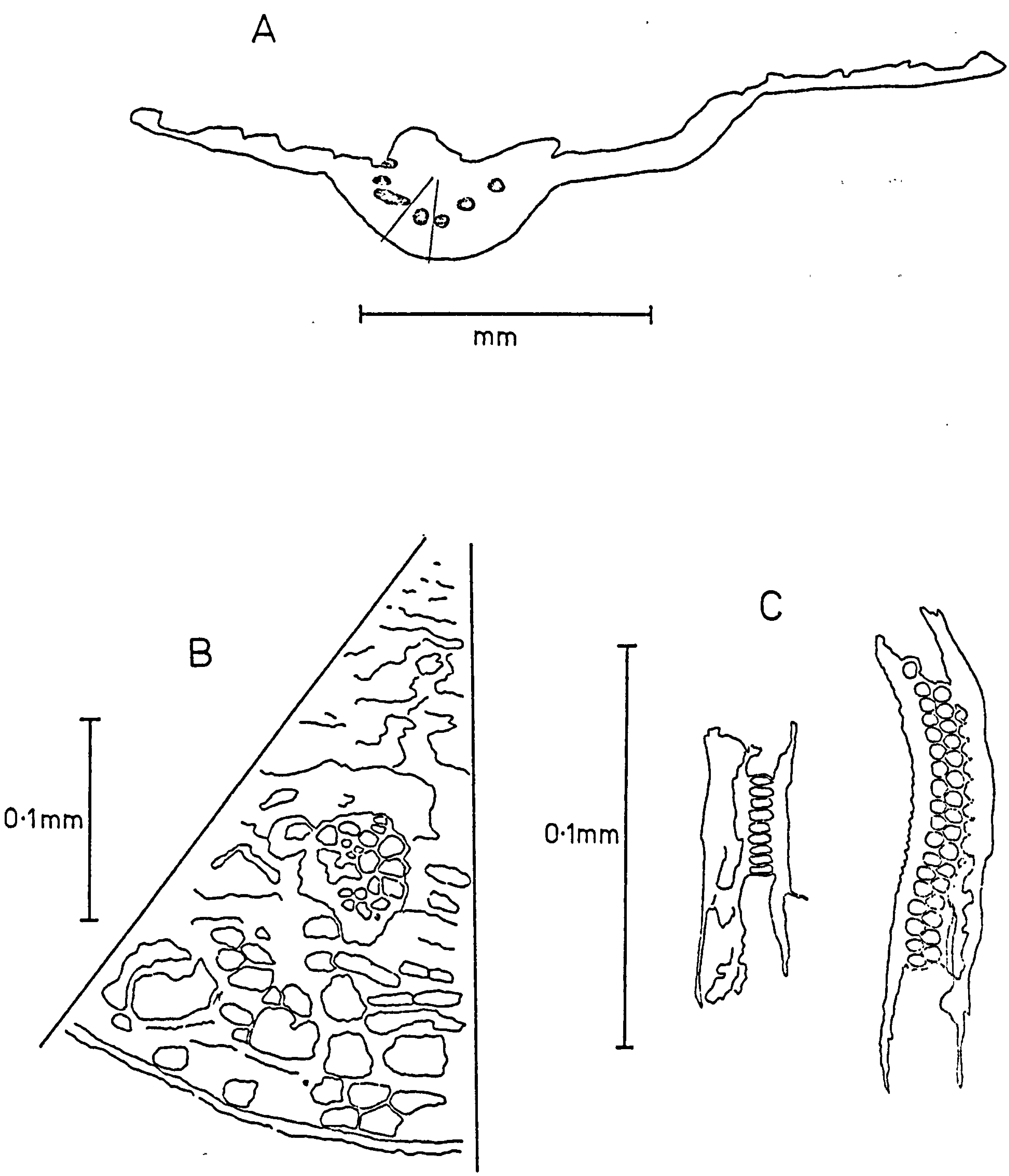
Both cellulose acetate pulls and attempted cuticle preparations were made from the organic layer which still remains on some of the pinnae. The pulls did not reveal any additional information that could not be obtained by direct observation. Good quality cuticles were impossible to extract and what appeared to be cuticles under low power magnification became much less cuticle-like under higher power, there being no cellular detail visible. These were either very poorly preserved cuticles or some form of pseudo-cuticle.

Sections of the rachis of the frond were made and revealed poorly preserved cellular structures. This partial success prompted a search for better material and on fracturing P.426.6, a further example of this frond was obtained and although only fragmentary, the rachis appeared well preserved. Sections of this rachis were made in both transverse and longitudinal planes and provided very good results. Sections were also made of the pinnae but results proved disappointing.

Plates 8:29, 8:30 and 8:31 and Text Figure 25 illustrate the details seen in the peel sections of the rachis.

The rachis measures approximately 0·78 millimetres wide by 0·5 millimetres thick and contains the remains of seven vascular bundles arranged in a flattened V shape. It has a crushed epidermis, a two layered cortex (possibly containing storage products and sclereids ?), vascular bundles and a poorly preserved parenchymatous pith.

In longitudinal section (see Plate 8:32 and Text Figure 25:C) the




Text Figure 25: A. <u>Pterophyllum dentatum</u> sp. nov. Section through rachis and pinnae. 3·0mm. wide x 0·5mm. thick. Slide Number 38, Specimen Number P.426.6

B. <u>Pterophyllum dentatum</u> sp. nov. Detail of single vascular bundle. Slide Number 38, Specimen Number P.426.6

C. <u>Pterophyllum dentatum</u> sp. nov. Detail of tracheid pitting. Larger tracheid measures 120µm long. Slide Number 45, Specimen Number P.426.6

pitting seen on the tracheids is mostly of the reticulate type, although some were observed with scalariform pitting (probably representing the small amount of protoxylem present).

Specific identification has proved difficult even though the frond has some very characteristic features and comparisons have been made with pinnate fronds which exhibit the dissection of the pinnae at the apex (refer to Plate 7:28, Text Figure 26 and Table 8).

Comparison with living *Macrozamia* sp. from Australia is quite enlightening in terms of the general morphology (Plate7:28 and Text Figure 26:D). *Cycas* compares quite well in its anatomy, having a V shaped arrangement of the vascular bundles.

Bose (1953) has described the rachis anatomy of *Ptilophyllum amarjalense* and this again has a V shaped arrangement of the bundles, although in this species, the bundles are two layered and number over forty in total. He describes the rachis as having a rectangular epidermis, hypodermis and ground tissue of isodiametric to oval cells with or without air spaces. In longitudinal sections the xylem elements show scalariform thickenings and the cells of the phloem are polygonal in outline and mostly not well preserved.

Rao (1948) has described the anatomy of another species of *Ptilophyllum*, *Ptilophyllum cutchense* but few details were given.

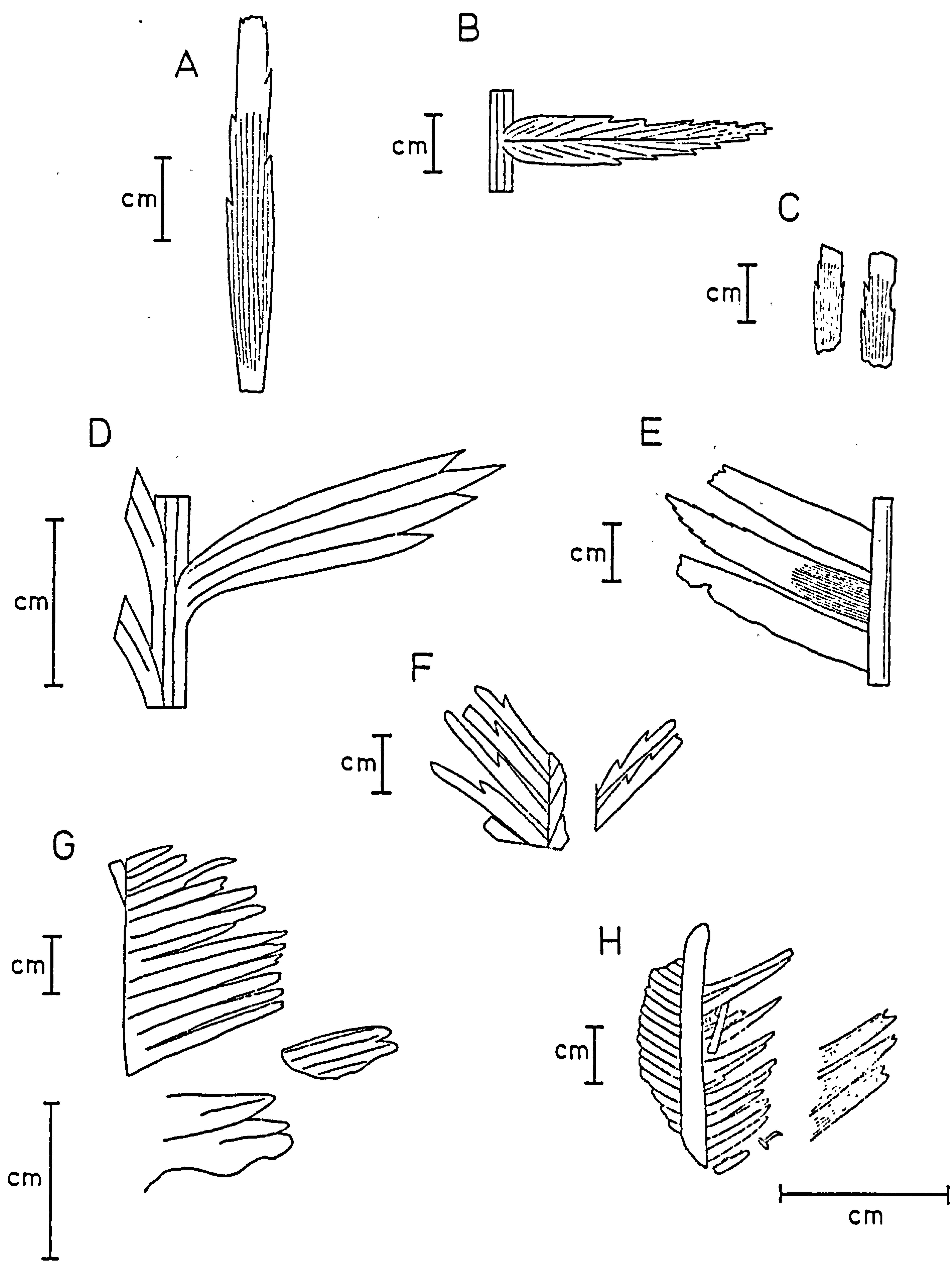
From Table 8, the best comparison can be made with *Pterophyllum incisum* described by Sahni and Rao (1933).

This specimen was referred to as a new species on account of the incised tips of the pinnae which they suggested make it a type intermediate between *Pterophyllum* and *Anomozamites* Schimper 1870.

*Pterophyllum incisum* differs from the present form in that the frond is larger, has a greater number of veins per pinna and that the apices of the pinnae are incised only one or two times, thus giving a maximum

| SPECIES | REFERENCE | AGE | ILLUSTRATION |
|---|---|---|---|
| Almargemia dentata (Heer) Florin | Florin (1933), Teixeira (1948) | Mesozoic - Cretaceous | Text Figure 26:F |
| cf. Ctenis sp. | collected by C. R. Hill | Jurassic | Text Figure 26:A |
| Encephalartites leipzigii Vakhrameev | Timura & Shinji (1971) | Mesozoic | Text Figure 26:C |
| Macrozamia sp. | collected by W. S. Lacey | Extant | Text Figure 26:D |
| Moltenia dentata | Du Toit (1927) | Triassic | not illustrated |
| Neozamites elongata Kimura & Sekido | Timura & shinji (1971) | Lower Cretaceous | Text Figure 26:B |
| Pterophyllum bifurcatum | Suryanarayana (1954) | Jurassic | Text Figure 26:H |
| Pterophyllum incisum | Sahni & Rao (1933) | Mesozoic | Text Figure 26:G |
| Pterophyllum sp. | Delevoryas (1971) | Jurassic - Cretaceous | Text Figure 26:E |

Table 8. Possible comparisons with Pterophyllum dentatum sp. nov.




Text Figure 26: A. cf. Ctenis sp. (genus x)
B. Neozamites elongata
C. Encephalartites leipzigii
D. Macrozamia sp.
E. Pterophyllum sp.
F. Almargemia dentata
G. Pterophyllum incisum
H. Pterophyllum bifurcatum

of only three lobes.

No other close comparisons with the present material seem possible and it is suggested to erect a new species for these specimens. As the material has many characters in common with the genus Pterophyllum, it is proposed to name the specimens Pterophyllum dentatum sp. nov.

Diagnosis: Frond pinnate; pinnae linear with parallel margins, usually 1·5 - 3·0 mm. wide by about 2·0cm. long. Veins parallel, unbranched, 4 - 5 in each pinna, tips of pinna incised 3 - 4 times in an unequal manner, the resulting lobes bluntly pointed and veins appear to stop short of the lobes. Rachis approximately 0·75mm. wide by 0·5mm. thick with at least seven bundles arranged in a flattened V shape, made up of thin epidermis, cortex (hypodermis) 6 - 10 cells thick and undifferentiated pith (ground tissue). Tracheids with reticulate, rarely scalariform pitting. Cuticle and reproductive structures unknown.

## CONIFEROPSIDA

### Genus *Pagiophyllum* Heer 1881

The genus *Pagiophyllum* is often used for sterile coniferous branches characterized by closely set thick leaves of falcate form, similar to those of *Araucaria excelsa*, *Cryptomeria japonica*, some species of *Dacrydium* and other living conifers.

Seward (1919) suggested that the genus encompass sterile fragments having the *Araucaria excelsa* type of leaf, which through the absence of cones cannot be safely assigned to another genus.

*Elatocladus* Halle (1913) includes sterile shoots of the *Taxites* type, except for *Elatocladus heterophylla*, which bears both distichous, linear leaves and crowded scale-like leaves similar to those of *Brachyphyllum*.

Seward (1919) states that it is desirable to retain *Brachyphyllum* and *Pagiophyllum* for sterile shoots exhibiting no well marked dimorphism and bearing fleshy, adpressed leaves and four-sided falcate leaves respectively.

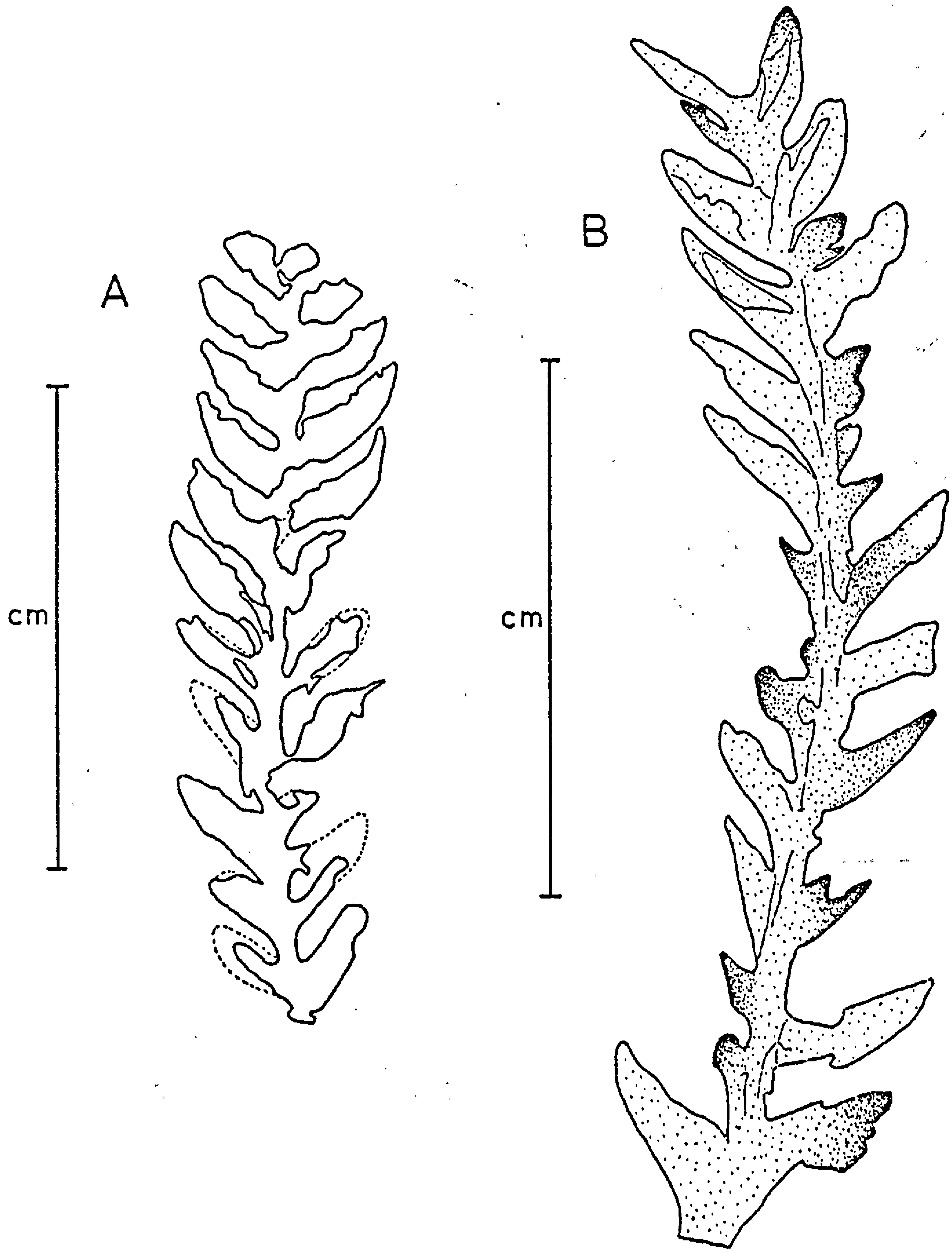
The differences between *Brachyphyllum* and *Pagiophyllum* have been fully explained on a more quantitative basis by both Kendall (1948) and Wesley (1956).

### *Pagiophyllum* sp.

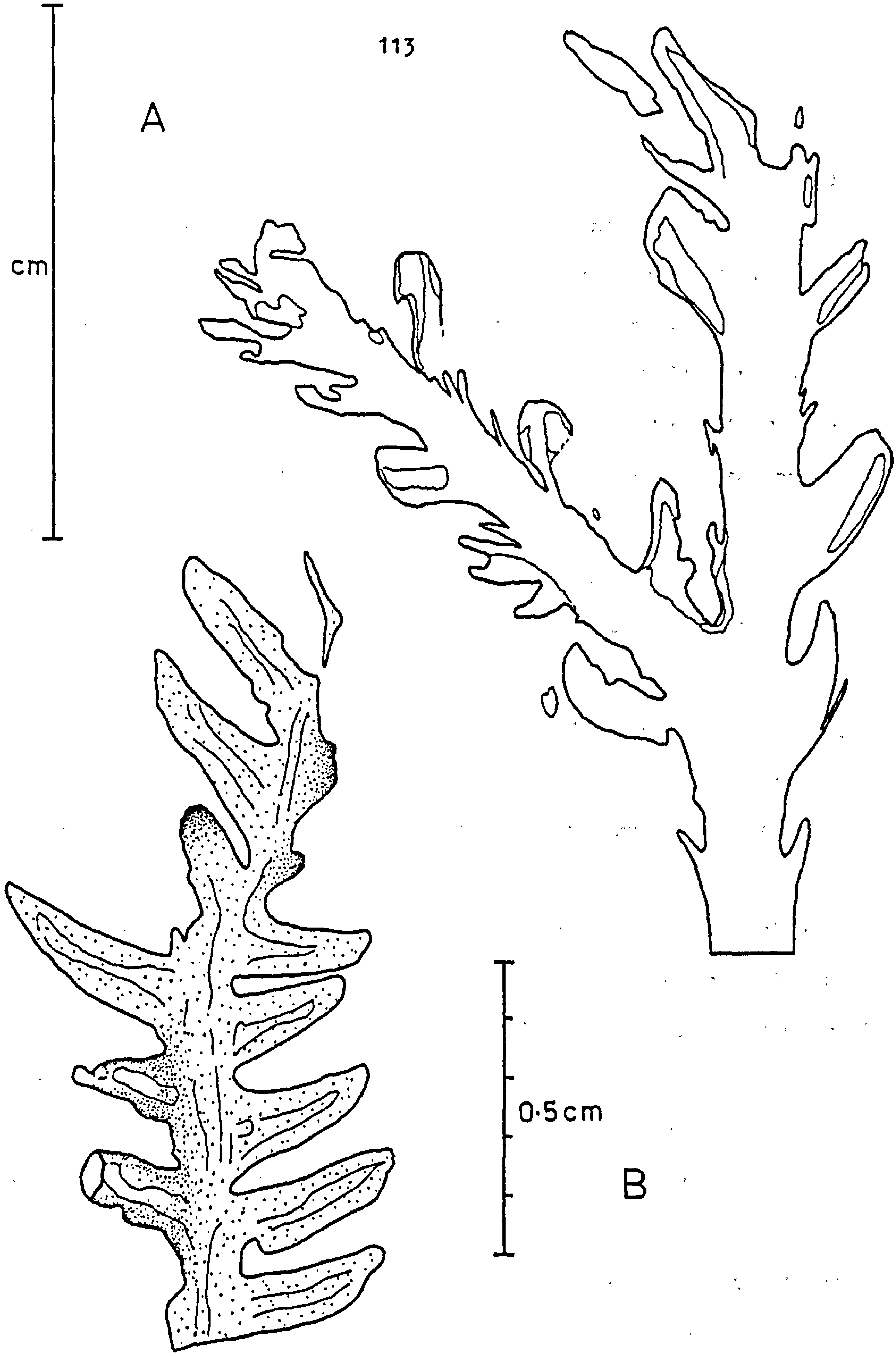
(Plates 9:33 - 36 and 10:37, Text Figures 27 - 31)

Large numbers of conifer shoots, measuring 1 - 7 centimetres long by 2 - 7 millimetres wide with spirally arranged, falcate leaves measuring up to 5·0 millimetres long and 1·0 millimetre wide have been found in the P.224 sub-collection.

The leaves have decurrent leaf bases, are sometimes adpressed to the the main stem and appear to be arranged in a 3/8 phyllotaxy. Many of the specimens show considerable flattening, giving the appearance that




Text Figure 27: A. Pagiophyllum sp. 16·5mm. long x 4mm. wide.
Specimen Number P.224.50
B. Pagiophyllum sp. 2·3cm. long x 4·7mm. wide.
Specimen Number P.224.42




Text Figure 28; A. Pagiophyllum sp. 12·4mm. long x 5mm. wide.
Specimen Number P.224.49
B. Pagiophyllum sp. 13·5mm. long x 6mm. wide.
Specimen Number P.224.31

the leaves were aligned along a single plane.

Specimens illustrated in Plates 7:33 - 36 and 10:37 and also in Text Figures 27 and 28 reveal the wide range of apparent morphological variation exhibited by these conifer remains. This difference is enhanced as specimens have undergone different levels of compression.

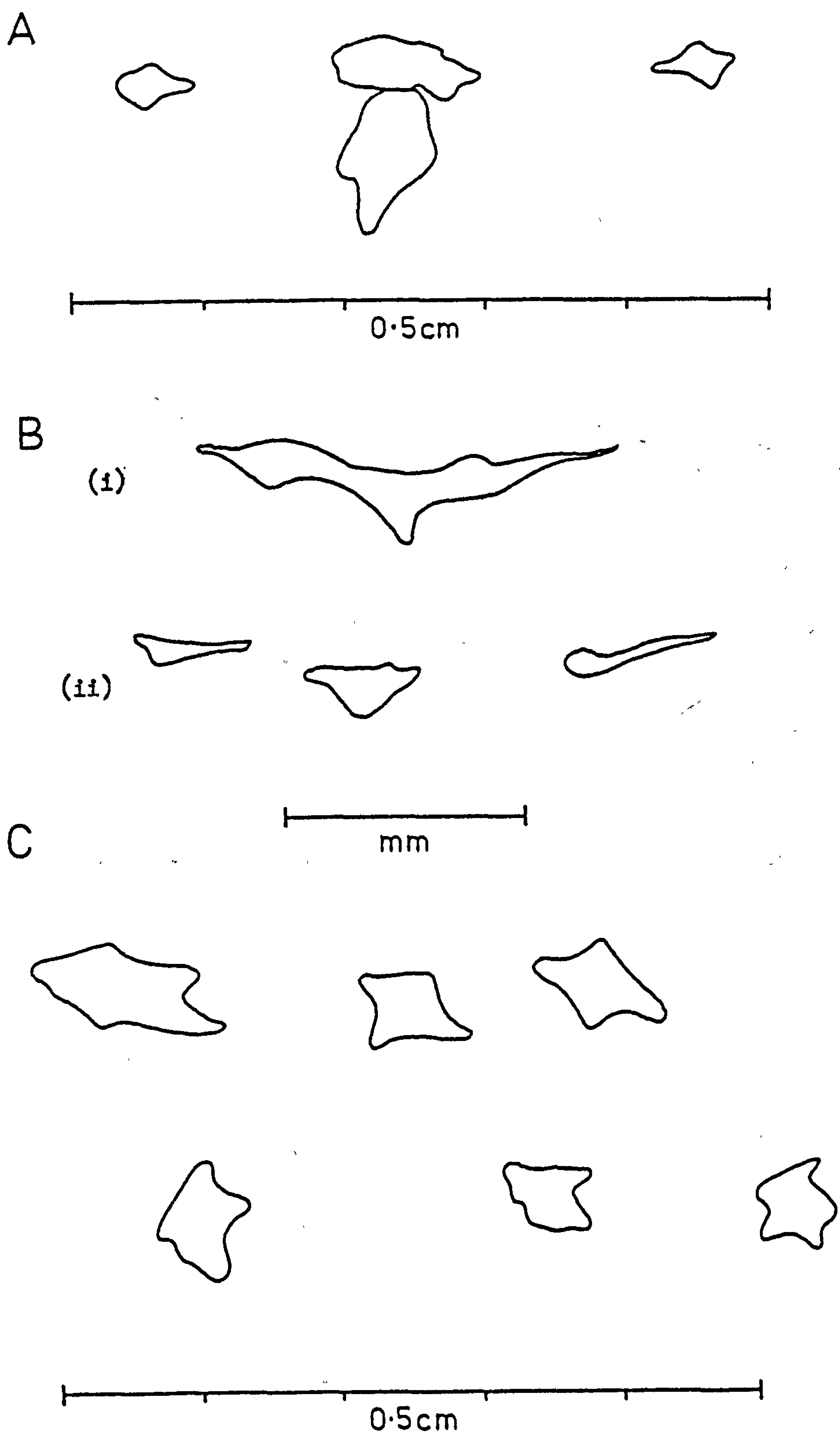
On detailed examination, however, all of the conifer fragments were recognized to conform to the same general pattern with respect to size, leaf shape and phyllotaxy and probably simply represent the amount of phenotypic variation that would be present in a single taxon.

Text Figures 27:B and 28:B show specimens that were drawn from transfer preparations and includes details of the axes three-dimesional appearence using a stippling technique. In this instance, the dark shaded leaves are in the background (ie. are partially buried in the matrix), the even shaded leaves are approximately parallel with the bedding plane and the light shaded leaves are in the foreground, although most of these will have broken away.

From peel sections made on transfered specimens, the cross section of a leaf appears four sided (rhomboidal), composed of a dark uniform carbonaceous substance in which no anatomical details could be discerned (refer to Text Figure 29:C). Further sections were made of complete shoots but these only confirmed that the specimens had indeed undergone considerable compression and anatomical detail, even in the thicker axes was not preserved (see Text Figure 29:A and B).

The remains of two possible cones were also discovered and the first was made when a transfer of one of the best preserved shoots (illustrated in Plate 9:34 and Text Figure 27:B) was made.

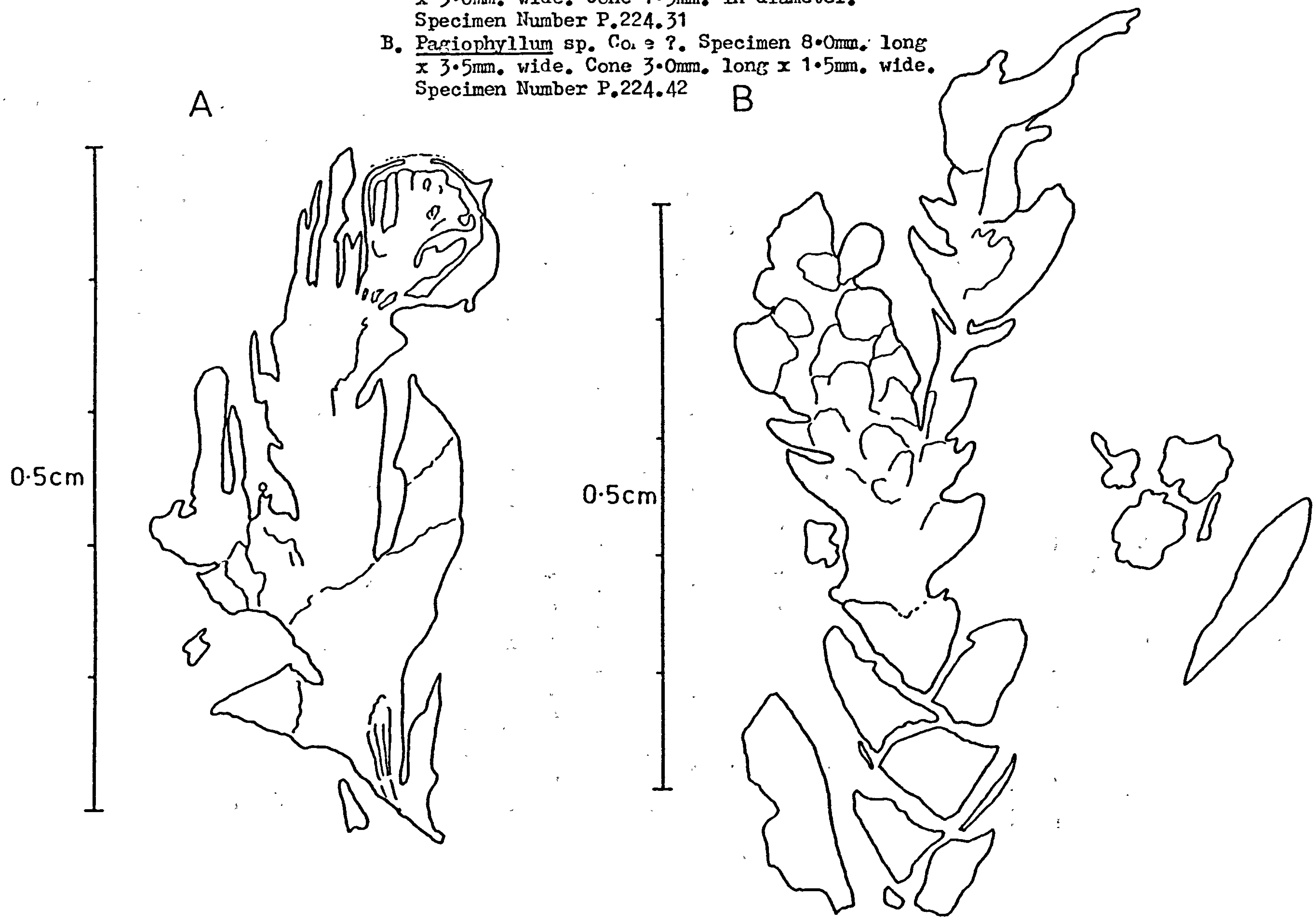
The possible cone is 3·5 millimetres long by 1·8 millimetres wide and seems to have been borne laterally to the main axis and is composed of tightly packed spirally ? arranged scale leaves. The bract and seed




Text Figure 29; A. *Pagiophyllum* sp. Axis section of Text Figure 28:A. Slide No.48. Specimen Number P.224.49
B. *Pagiophyllum* sp. Axis sections of Text Figure 27:A. Slide No. 50. Specimen Number P.224.50
C. *Pagiophyllum* sp. Leaf section of Text Figure 27:B. Slide No. 54. Specimen Number P.224.42

Text Figure 30: A. Pagiophyllum sp. Cone ?. Specimen 6·5mm. long x 3·0mm. wide. Cone 1·5mm. in diameter. Specimen Number P.224.31

B. Pagiophyllum sp. Cone ?. Specimen 8·0mm. long x 3·5mm. wide. Cone 3·0mm. long x 1·5mm. wide. Specimen Number P.224.42



scale are not separately distinguishable (see Text Figure 30:B).

The second possible cone was found by binocular examination of a small weathered fragment, P.224.31. A subsequent transfer of the shoot was carried out to enable observation of both sides of the specimen. This showed beyond doubt that the object was spherical, but furnished no additional information about its structure.

The possible cone, as with the previous example, appears to be borne laterally, measures approximately 1·5 millimetres in diameter and is composed of overlapping scale leaves (see Text Figure 30:A).

It is likely that this may be either an immature male cone or a vegetative bud.

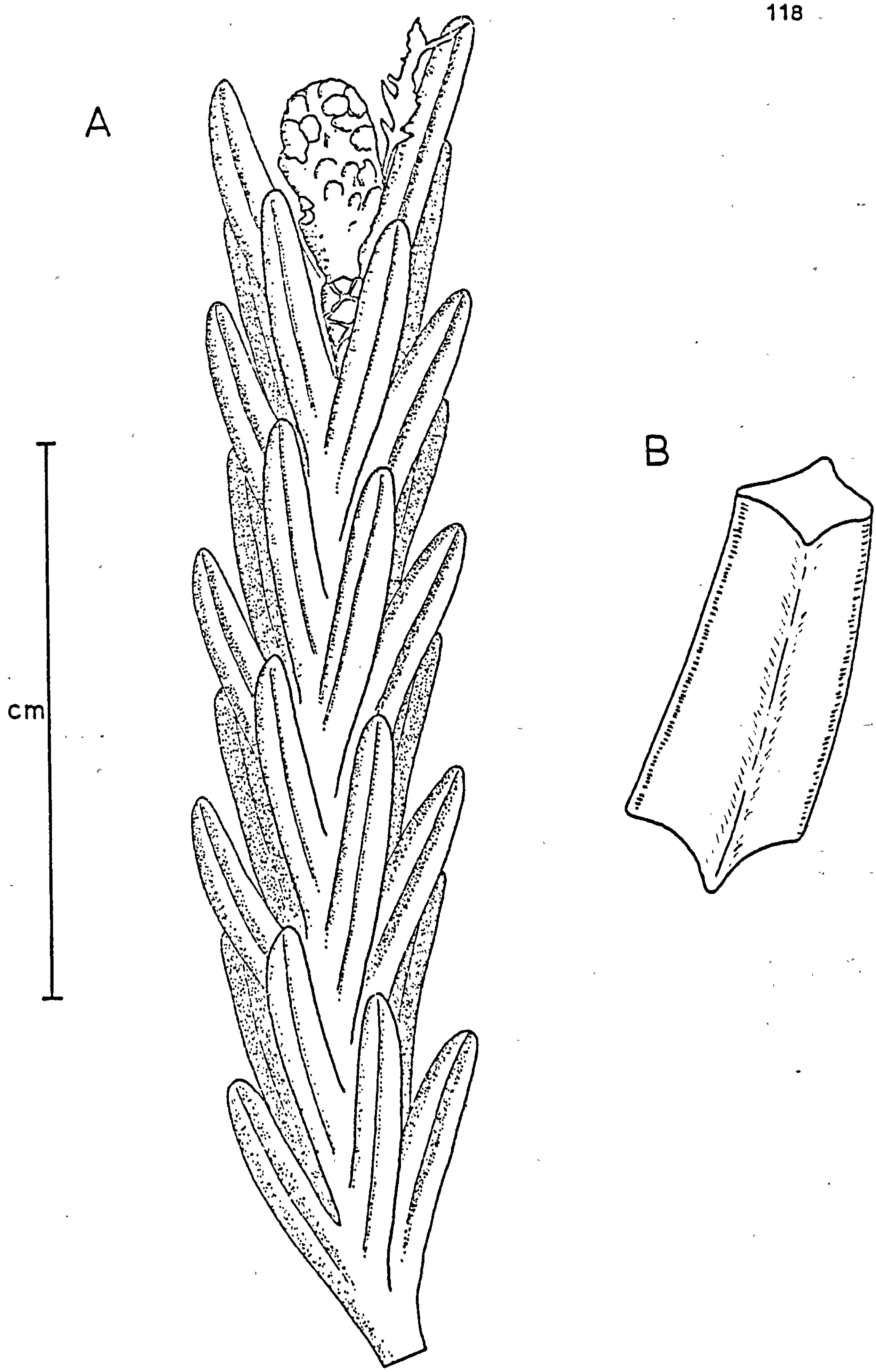
An idealized reconstruction of a conifer shoot based on the specimen illustrated in Plate 9:34 and Text Figures 27:B and 30:B was attempted and includes the first of the possible cones found. This is illustrated in Text Figure 31 and also includes detail of a single sectioned leaf.

As reproductive organs have not been identified with any certainty, it is proposed to include these Triassic conifer remains within the genus _Pagiophyllum_, as much of the material has close resemblaces to both _Araucaria excelsa_ and _Cryptomeria japonica_. Although most of the species of _Pagiophyllum_ have been descibed from Jurassic deposits, age is not a criterion for taxonomic division.

Comparisons have been made with over twenty species of _Pagiophyllum_, as well as fertile _Pagiophyllum_-like species and these are listed in Table 9. The most favourable comparisons include _Pagiophyllum heerianum_, _Pagiophyllum setosum_, _Nothodacrium warreni_ and _Rissikia apiculata_.

_Pagiophyllum heerianum_ is very similar in size, although the leaves are slightly longer and thicker than the present material and the leaf apex is always acute.

_Pagiophyllum setosum_ is again of similar size, but in this case the leaves are shorter and the apex always rounded.




Text Figure 31: A. Pagiophyllum sp. Reconstruction
B. Pagiophyllum sp. Detail of single leaf.

| SPECIES | REFERENCE | SHOOT WIDTH | LEAF ARRANGEMENT | LEAF OR LF. BASE SIZE | LEAF LENGTH | LEAF APEX |
|---|---|---|---|---|---|---|
| Pagiophyllum connivens | Kendall (1948, 1952) | 8 - 27mm. | Spiral 2/5 | 5mm. | 12mm. | Acute |
| " crassifolium | Halle (1913) | 8 - 16mm. | " - | 1·5 x 1·5mm. | up to 7mm. | " |
| " curvifolium | Jacob & Shukla (1955) | 6mm. | " - | - | 3 - 8mm. | Pointed |
| " feistmantel | Halle (1913) | 7 - 15mm. | " - | 4 x 4mm. | 2 - 4mm. | " |
| " heerianum | Halle (1913) | 5 - 6mm. | " - | 1·5 x 1·5mm. | 4 - 6mm. | Acute |
| " insigne | Kendall (1948) | 13 - 18mm. | " 3/8 | 5 x 2·5mm. | 12mm. | " |
| " jemmetti | Walkom (1918) | 5mm.+ | " - | 5mm. | 10mm. | Rounded |
| " liasinum | Teixeira (1948) | 3 - 12mm. | " - | 2 - 3mm. | 6 - 8mm. | Pointed |
| " lusitanicum | Teixeira (1948) | 2 - 8mm. | " - | 2 - 4mm. | 3 - 6mm. | " |
| " magnipapillare | Wesley (1956) | 2 - 3mm. | " 3/8 | 1·5 x 1mm. | 1mm. | Blunt |
| " masculosum | Kendall (1948, 1952) | 5 - 8mm. | " 3/8? | 4 x 4mm. | 4 - 5·5mm. | Rounded |
| " ordinatum | Kendall (1948) | - | - - | 8mm. | 12mm. | Pointed |
| " peregrinum | Kendall (1948) | 4 - 12mm. | Spiral 3/8 | 4 - 6mm. | 4 - 12mm. | Acute |
| " revoltinum | Wesley (1956) | 19mm. | " 2/5 | 1·75 x 1·5mm. | 11 - 12mm. | Rounded |
| " rigidum | Harris (1952) | 4 - 5·5mm. | " - | 0·7mm. | 3 - 4mm. | Acute |
| " robustum | Wesley (1956) | 13 - 18mm. | " 5/13 | 5 x 4mm. | 8 - 10mm. | Blunt |
| " rotzoanum | Wesley (1956) | 10 - 15mm. | " 3/8 | 3 - 6mm. | 4 - 5mm. | Pointed-round |
| " setosum | Jacob & Shukla (1955) | 3 - 6·5mm. | " - | - | 2 - 3·5mm. | Rounded |
| " sewardi | Kendall (1948) | 8mm. | " 3/8 | 9mm. | 10mm. | Acute |
| " valdassense | Wesley (1956) | 10mm. | " 3/8 | 3·5 x 3·5mm. | 6·5 - 7mm. | Upcurving tip |
| " veronense | Wesley (1956) | 9mm. | " 2/5 | 2·5 x 2mm. | 7mm. | Blunt |
| " vicetinum | Wesley (1956) | 10mm. | " 3/8 | 5 x 3·5mm. | 1·5mm. | " |
| Voltzia ribeiroi | Teixeira (1948) | 4 - 9mm. | " - | 3 - 4mm. | 4 - 10mm. | Pointed |
| Voltziopsis africanum | Townrow (1967d) | 7 - 13mm. | Twisted | 3 - 4mm. | 3 - 7mm. | Obtuse |
| " angusta | Townrow (1967d) | 4 - 9mm. | Spiral - | 3 - 4mm. | 3 - 10mm. | Acute |
| " wolganensis | Townrow (1967d) | 8mm. | Twisted | 3 - 4mm. | 10 - 30mm. | " |
| Rissikia apiculata | Townrow (1967a) | 2 - 16mm. | Spiral 3/8? | 1mm. | 4 - 10mm. | Pointed |
| Nothodacrium warreni | Townrow (1967b) | 2 - 4mm. | " 3/8? | 0·75 - 1·5mm. | 1·5 - 3·5mm. | Acute |

Table 9. Possible comparisons with Pagiophyllum sp.

Nothodacrium warreni compares very well in terms of size and overall leaf dimensions, although the leaves are slightly shorter and are given off at a shallower angle to the main axis. The possible reproductive organs show no close comparison.

Rissikia apiculata is again very similar, having very similar shaped and sized leaves, but differs in that its maximum dimensions are much greater than the Livingston Island material. As with the previous species, the fertile organs showed no comparison.

With lack of any cuticle evidence, it would be unwise to erect a new species for this new material and it will be thus referred to as Pagiophyllum sp. until more evidence (reproductive or epidermal) is available.

## Ginkgoales

### Ginkgoaceae

### Genus *Ginkgoites* Seward 1919

This genus is restricted to leaves that are regarded as fossil members of the Ginkgoales and are similar to leaves of the present day *Ginkgo biloba*.

Confusion often arises with the closely related genus *Baiera* which agrees in shape with *Ginkgoites* but is distinguished by the greater number and smaller breadth of the linear segments. In both *Ginkgoites* and *Baiera* the veins are dichotomously branched.

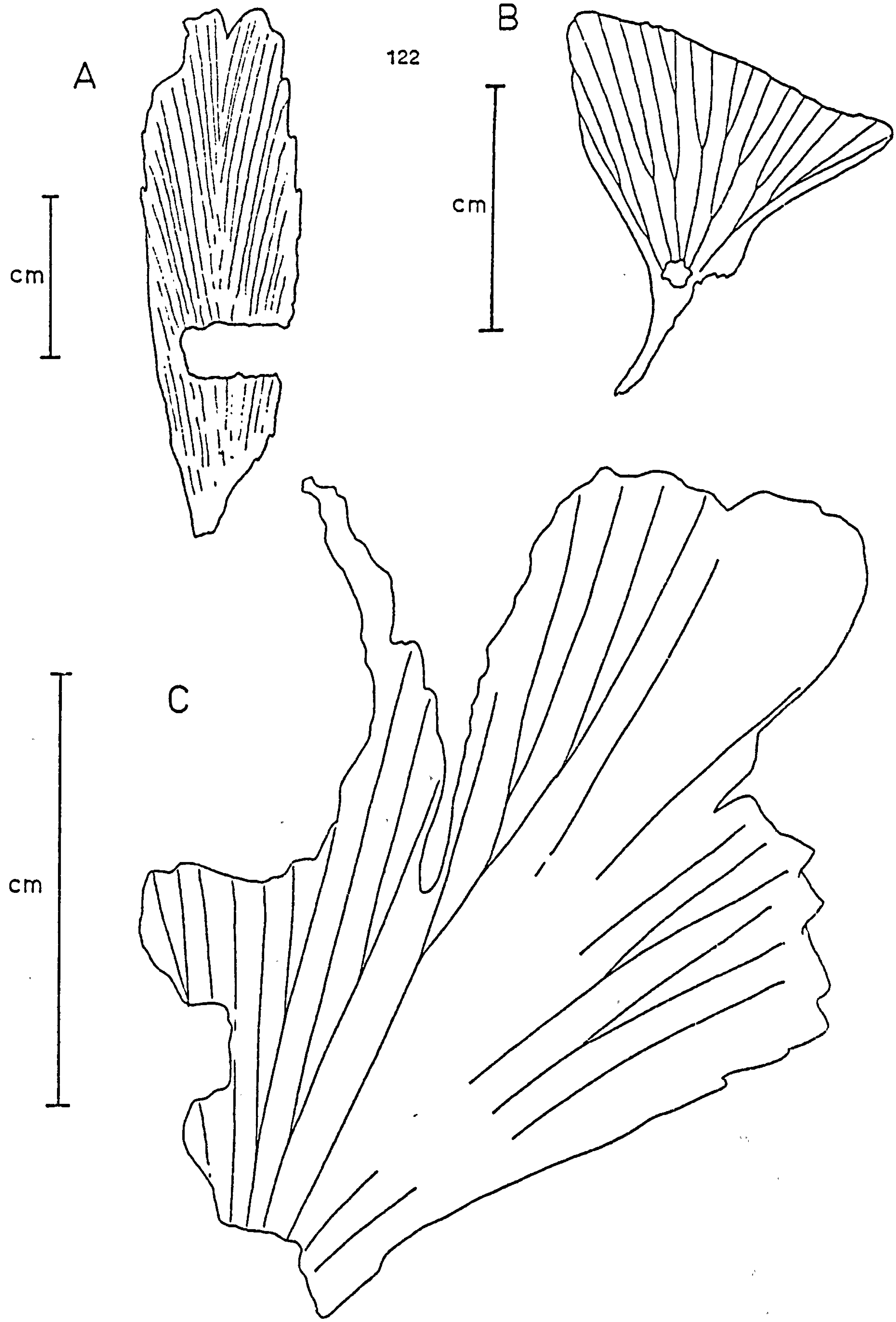
#### *Ginkgoites* sp.

(Plates 10:38 and 10:39, Text Figure 32)

In total, three specimens were recognized and one of these was found during the re-examination of the Hobbs collection, but not described by Orlando (1968).

The first specimen is of an elongate, forked impression of a leaf with a petiole and measures 3·3 centimetres long by up to 1·0 centimetre wide. It has very fine dichotomising venation, with three or possibly four dichotomies discernable and the veins have a density of four to five per millimetre of lamina (see Text Figure 32:A). The missing lamina is due to a chance fracture exposing an underlying axis.

The second specimen (Plate 10:38 and Text Figure 32:B) consists of a fragment of lamina measuring 1·4 centimetres long by 1·3 centimetres wide and possesses very fine repeating dichotomous venation with a vein density of two to three per millimetre. Only part of the petiole has been preserved and this specimen probably represents no more than half of the original leaf. At first the specimen was suspected of belonging to *Chiropteris* (refer to illustration on page 430, Seward, 1911) but on closer examination the veins were seen to dichotomize only and no anastomosing (characteristic of *Chiropteris*) was present.




Text Figure 32: A. Ginkgoites sp. 3·3cm. long x 1·0cm. wide.
Specimen Number P.224.48
B. Ginkgoites sp. 1·4cm. long x 1·3cm. wide.
Specimen Number P.224.27
C. Ginkgoites sp. 2·25cm. long x 1·70cm. wide.
Hobbs Specimen Number P.101.25

The third specimen (see Plate 10:39 and Text Figure 32:C) is by far the best of the three and as it was found in the Hobbs collection, it must have been overlooked by Orlando (1968).

The specimen measures 2•25 centimetres long by 1•7 centimetres wide and has a deep division of the lamina, the originality of which was verified by judicious degaging of the surrounding matrix to reveal the entire apical part of the lamina. The venation is seen to be separate for each of the two lobes, as occurs in living Ginkgo biloba and shows repeated dichotomies, with a density of three to four veins every two millimetres.

All three specimens show dichotomous venation and two have apical grooves in the lamina and possess the remains of petioles. These characters suggest a ginkgoalean affinity and indicate that the specimens be included in the genus Ginkgoites rather than in more dissected types such as Baiera, Arctobaiera and Windwardia.

Harris (1935) uses several characters to distinguish species of Ginkgoites, these being the size, shape and degree of dissection of the leaf; form of apex of the lobes; concentration of the veins and microscopic evidence. He also states that it is unsatisfactory or impossible to identify specimens of ginkgoalean leaves without the details provided by their cuticles and considers it useless to identify them with specimens whose cuticles are unknown.

As cuticles in the Antarctic specimens were not preserved, comparisons can only be made using gross morphology which is necessarily of limited value.

The specimens have been compared with many species of Ginkgoites (refer to Table 10), but on the fragmentary evidence available, all of the specimens could be included in Gingoites digitata, a near cosmopolitan species with a great range of variation (see page 17, Seward, 1919). Until more evidence is available it would be better to include

| SPECIES | REFERENCE | AGE |
|---|---|---|
| Ginkgoites acosmia | Harris (1935) | Jurassic |
| " adiantoides | Seward (1919) | Tertiary |
| " antarctica | Du Toit (1927) | Triassic |
| " bidens | Jones & de Jersey (1947) | Triassic |
| " crassipes | Seward (1919) | Lower Mesozoic |
| " digitata | Seward (1919) | Jurassic |
| " dilatata | Teixeira (1948) | Jurassic |
| " fibriata | Harris (1935) | Jurassic |
| " flabellata | Seward (1919) | Jurassic |
| " geinitzi | Seward (1919) | Rhaetic |
| " ginkgoides | Jones & de Jersey (1947) | Triassic |
| " huttoni | Seward (1919) | - |
| " ipsviciensis | Jones & de Jersey (1947) | Triassic |
| " hermelini | Harris (1935) | Jurassic |
| " lobata | Seward (1919) | - |
| " magnifolia | Du Toit (1927) | Triassic |
| " minuta | Harris (1935) | Jurassic |
| " moltenensis | Du Toit (1927) | Triassic |
| " multinervis | Seward (1919) | Lower Cretaceous |
| " obovata | Harris (1935) | Rhaetic |
| " obrutscheuri | Seward (1919) | Jurassic |
| " pluripartita | Seward (1919) | Lower Mesozoic |
| " polaris | Seward (1919) | Jurassic |
| " sibiraca | Seward (1919) | Jurassic |
| " simmondsi | Jones & de Jersey (1947) | Triassic |
| " taeniata | Harris (1935) | Jurassic |
| " truncata | Seward (1919) | Lower Mesozoic |
| " whitbiensis | Seward (1919) | Jurassic |

Table 10. Possible comparisons with Ginkgoites sp.

all of the specimens under the name <u>Ginkgoites</u> sp.

## INCERTAE SEDIS

Form genus Taeniopteris Brongniart 1822

This genus was modified by Harris (1932) to include three sub-divisions. The first division contained specimens, having no cuticles, known to be the sterile leaves of ferns such as Marattiopsis and Danaeopsis; the second contained specimens in which the cuticle is absent or very poorly preservered as in Taeniopteris and the third included specimens with well preserved cuticles, with either cycad-like or bennettitalean-like stoma.

Genus Doratophyllum Harris 1932

Harris erected this genus for those leaves of the Taeniopteris type which were small, had the lamina attached to the sides of the rachis and which had stomata of the cycadean type.

Doratophyllum (Taeniopteris) tenison-woodsi (Etheridge) Harris
(Plate 10:40, Text Figure 33)

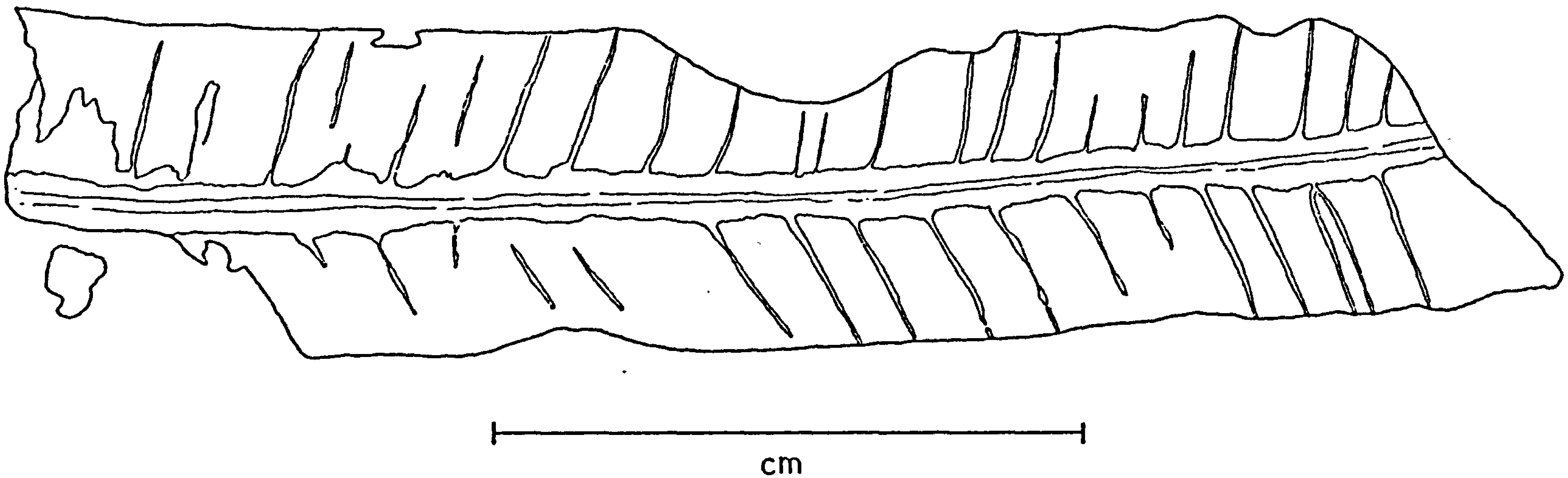
Five specimens were found altogether and four of these were contained on a single hand specimen. The best preserved frond measures 2·65 centimetres long by 0·5 centimetres wide, has a prominent midrib and sparse secondary venation.

The secondary veins were not seen at first (refer to Plate 10:40), but after a short period of etching with Hydrofluoric acid and careful use of steel needles to remove the softened matrix, the veins were revealed (see Text Figure 33:A).

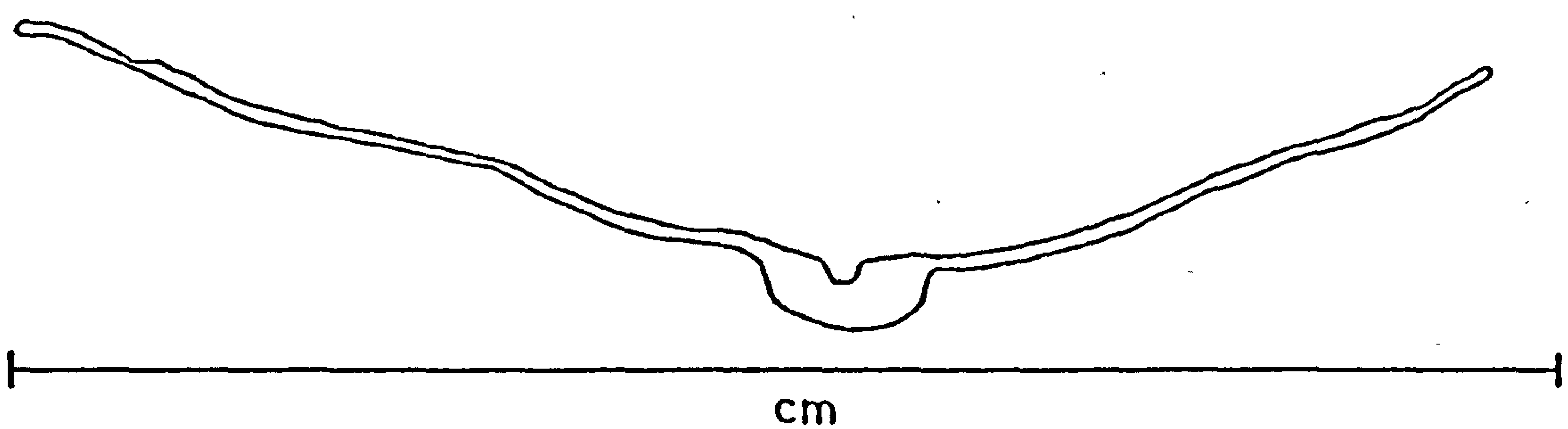
Most of the veins are unbranched and only a single vein exhibits a dichotomy and this occurs very close to the rachis. The veins are spaced 1·0 - 1·25 millimetres apart and are given off at an angle of about 65 degrees from the midrib.

Sections were obtained from specimens passing through the matrix and

A



B



Text Figure 33: A. Doratophyllum (Taeniopteris) tenison-woodsi
2·65cm. long x 0·50cm. wide.
Specimen Number P.224.36

B. Doratophyllum (Taeniopteris) tenison-woodsi
Section. 9·5mm. wide. Slide Number 59,
Specimen Number P.224.36

revealed a prominent groove on the upper surface of the midrib (refer to Text Figure 33:B). From sections, the fronds measure 6 - 10 millimetres wide with midribs 0•65 - 1•4 millimetres wide by 0•4 - 0•6 millimetres thick. No cellular detail was apparent in any of the sections.

In overall appearance, the specimens resemble Taeniopteris and Yabiella Oishi 1931, but on closer examination the marginal vein (very characteristic of Yabiella) is absent.

The specimens compare with Taeniopteris tenison-woodsi recorded from the Ipswich coal measures by Jones and De Jersey (1947). Further comparisons have also been made with specimens of this species housed in the British Museum (Natural History). Material from Denmark Hill in particular (Specimen number V21371), described as Taeniopteris tenison-woodsi is identical with the present material in respect to the size, pattern of secondary venation and the presence of a midrib groove.

The specimens are included in Doratophyllum (Taeniopteris) tenison-woodsi, even though the cuticle is not preserved in this material, on account of its identification with Taeniopteris tenison-woodsi.

<u>Hexagonocaulon</u> <u>minutum</u> gen. et sp. nov.

(Plates 11•41 -43, 12:44 - 47, 13:48 and 49, Text Figures 34 - 38)

Large numbers of axes conforming to the same general pattern, have been found in both the present material and in the earlier Hobbs collection. All of the axes are radially symmetrical, preserved in situ (ie. vertical to the bedding plane) and occur in various states of organization and preservation, but all are characterized by a hexapartite and sometimes a tripartite form.

The axes measure between 0•5 - 4•0 millimetres wide and the larger specimens may possess up to three concentric outer layers surrounding a hollow, hexagonal shaped 'stele' up to 1•0 millimetre in diameter (refer to Plates 11:41 and 43, 12:44 and 46 and Text Figures 34 and38).

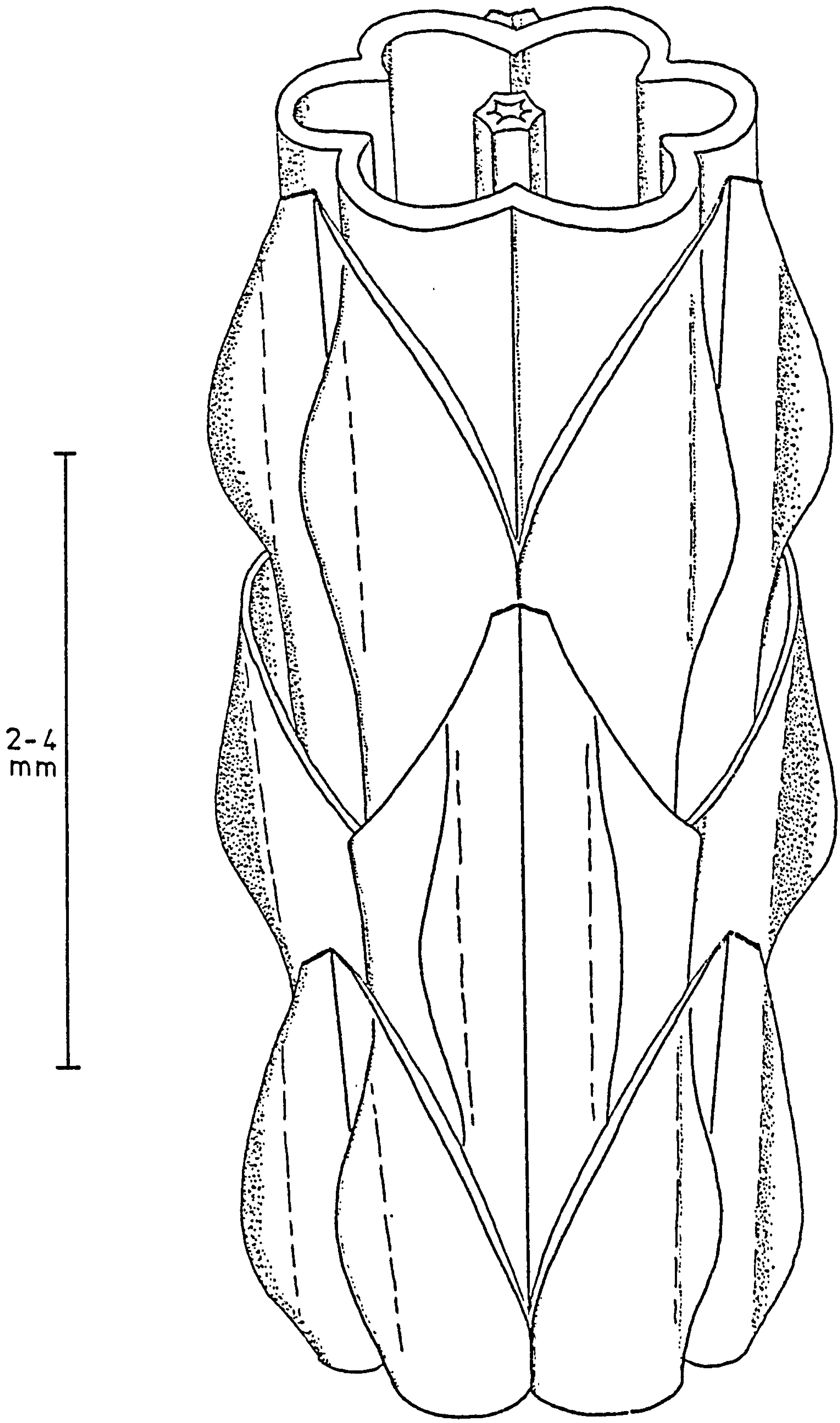
In transverse section, the stele contains iso-diametric to slightly radial elongate cells which appear to show some evidence of pitting and have the loose string of beads appearance under high magnification.

A series of vertical sections was made through one of the best preserved specimens (refer to Text Figure 36) and several of these sections passed through the stele. Plate 11:42 illustrates one of these sections.

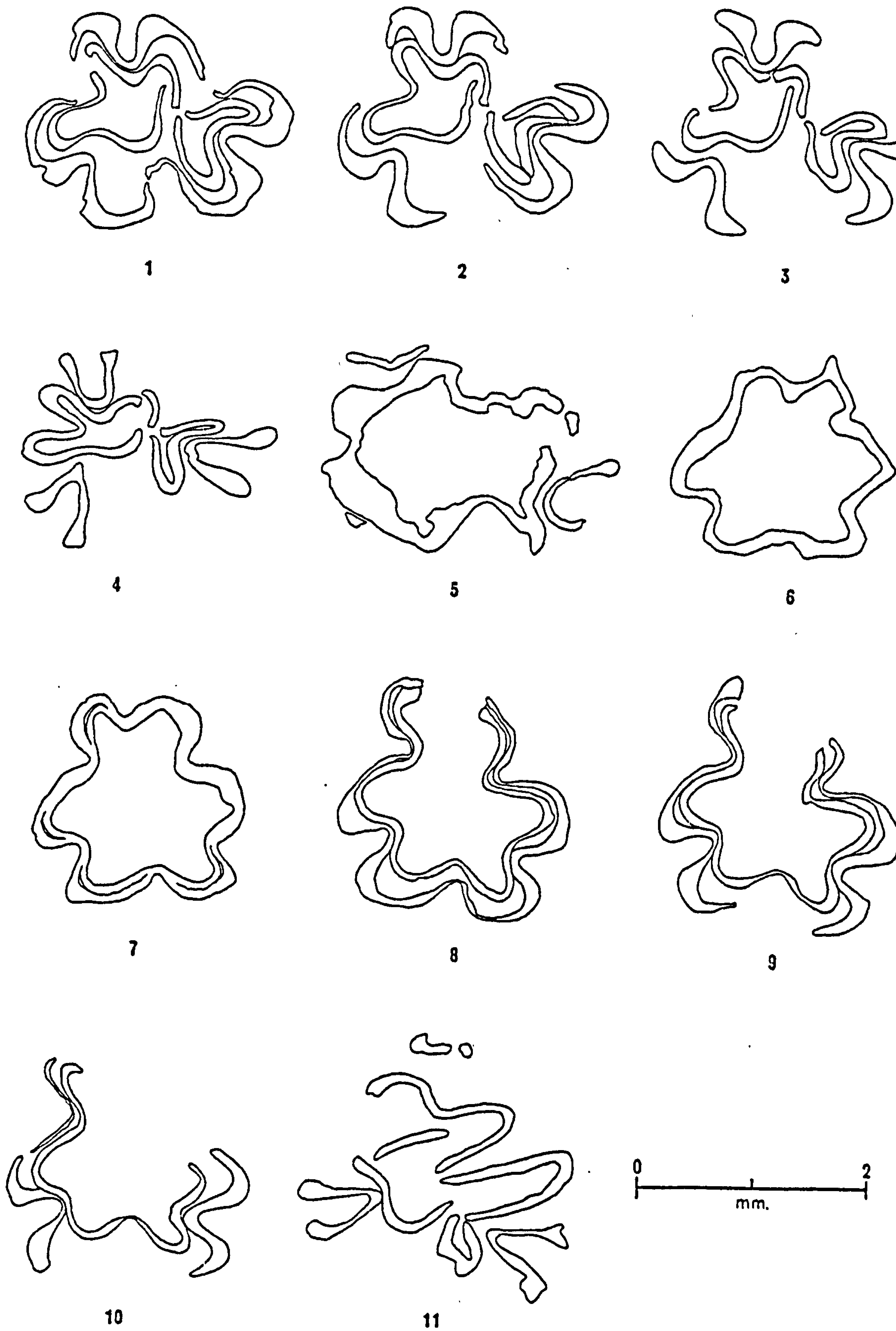
In the central stele the cells appear to be longitudinally elongated and in some sections the possible remains of annular or helical thickening is just discernible. This thickening is well seen in a very distorted longitudinal section (Slide Number 4), but unfortunately it is not known if this belonged to the present material.

Surrounding the stele there occurs poorly preserved parenchyma tissue and this was found to be preserved in only a few sections, the best example of which is illustrated in Plate 12:44. It can be seen as a shrunken ring between the outer tissues and inner stele.

From the vertical section in Plate 11•42, this tissue forms a plate or diaphragm connecting the outer tissues and stele and divides the axis up




Text Figure 34: Hexagonocaulon minutum gen. et sp. nov. Reconstruction. Axis measures between 2 - 4mm. wide.




Text Figure 35: Hexagonocauline minutum gen. et sp. nov. Transverse serial peel sections on which part of text figure 34 was based. Slide Numbers 12 - 18, Hobbs Specimen Number P.101.14

into compartments.

The outer tissue is made up of two to three concentric rings, each composed of six lobes or plates in which the outermost layer divides up into three flanged 'scale leaves'. From serial peel sections (refer to Text Figure 35) these scale leaves are given off from the outermost layer in an alternating sequence, possibly at every node, but this is not definite as the stele was not preserved in the specimen used for the serial peel sections.

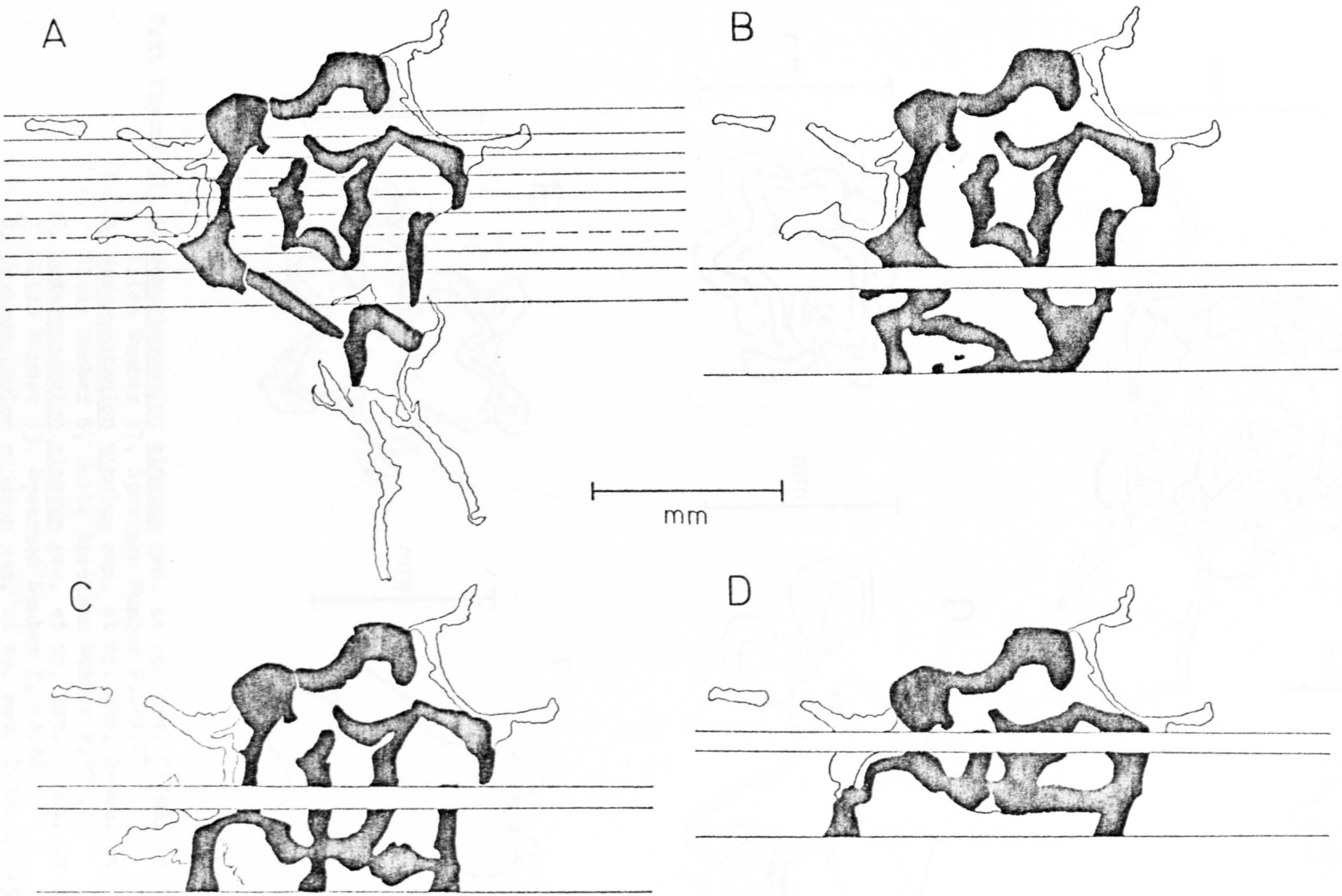
Plates 12:45, 12:47, 13:48 & 49 and Text Figure 37 illustrate the range of size and the variety of structure represented by these axes which have been recognized from both 1959 and 1975 collections.

From all of the information accumulated, a three dimensional reconstruction has been attempted (see Text Figure 34). This is an idealized diagram which was drawn from a model based on the serial peel sections and additional information derived from other sections and as a consequence may not bear an exact likeness to the original.

In the reconstruction, there is a single six-lobed layer bearing alternating whorls of three deeply bi-lobed or flanged scale leaves. In the centre is the hollow, hexagonal shaped stele which is probably connected to the outer layer by nodal diaphragms (this is not illustrated).

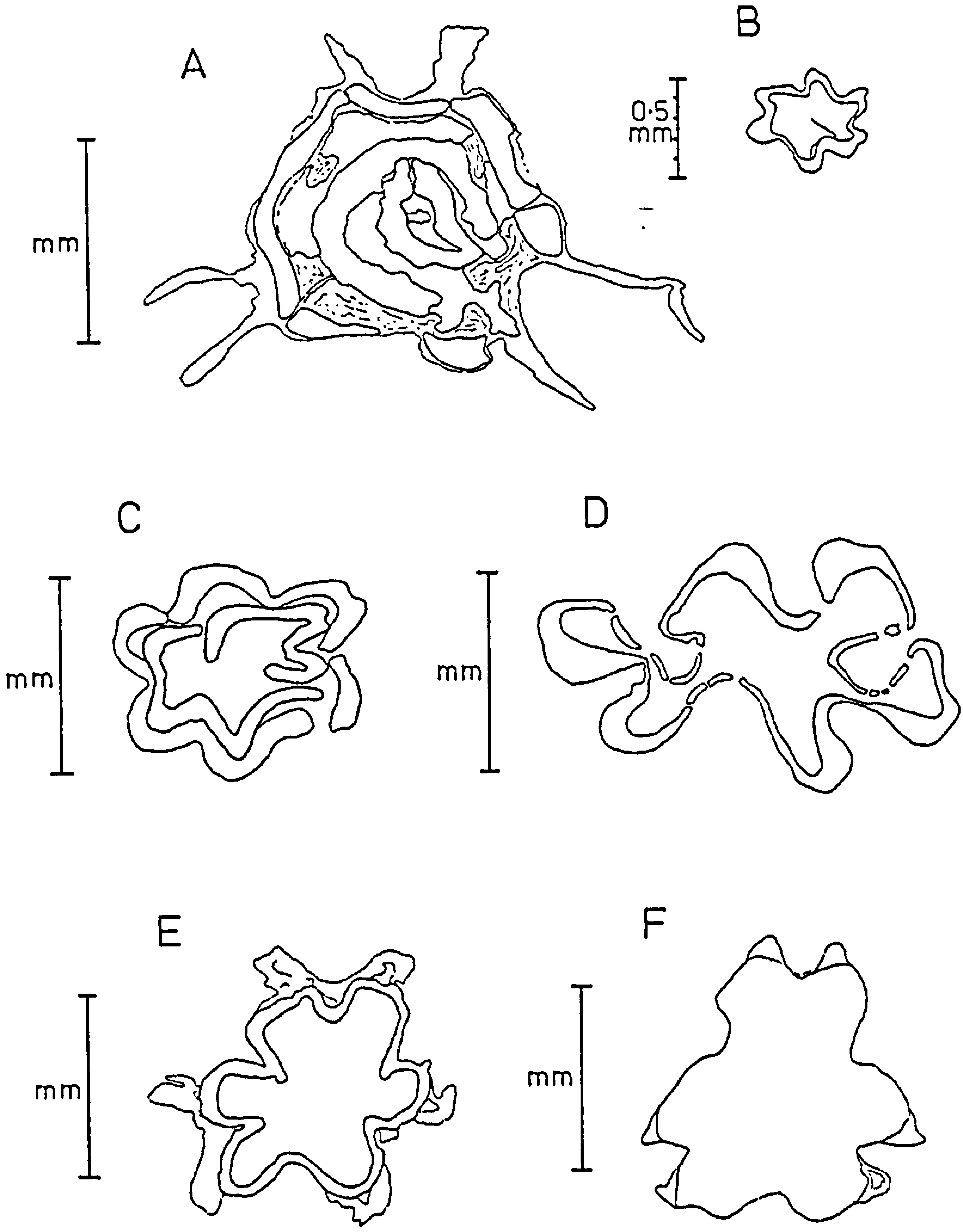
Specimens up to 10 millimetres in length have been found but the majority are considerably shorter than this and the flanges on the scale leaves can be up to 0•75 millimetres in length.

The diaphragm is made up of parenchyma-like tissue 1 - 2 cells in thickness, although one area occurs which appears to be four cells thick and although serial sections of the stele are few in number, some appear to show possible leaf gaps in the stele. Plate 12:44 also reveals what could be a leaf trace and which extends from the stele across the shrunken diaphragm and thence divides into two at the base of the leaf (see uppermost leaf in this illustration).

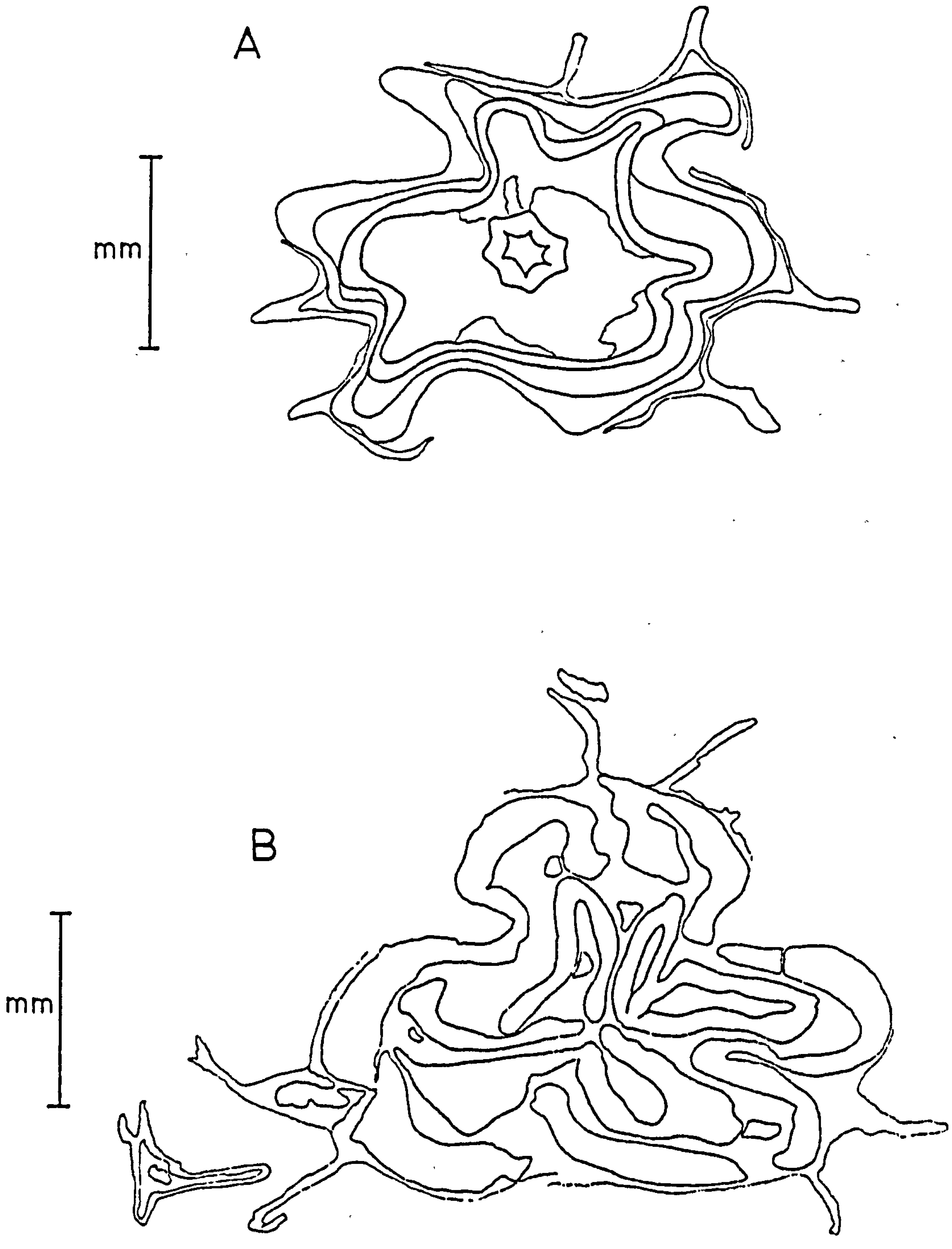



Text Figure 36: A. Hexagonocaulon minutum gen. et sp. nov. Transverse section. Slide Number 18, Specimen Number P.224.27

B - D. Hexagonocaulon minutum gen. et sp. nov. Transverse and corresponding longitudinal section, revealing nodal ? diaphragm. Slide Number 21, Specimen Number P.224.27




Text Figure 37: A. Hexagonocaulon minutum gen. et sp. nov. 2·7mm. in diameter. Slide Number 17, Specimen Number P.224.27
B. Hexagonocaulon minutum gen. et sp. nov. 0·6mm. in diameter. Slide Number 8, Hobbs Specimen Number P.101.25
C. Hexagonocaulon minutum gen. et sp. nov. 1·3mm. in diameter. Slide Number 33, Specimen Number P.224.48
D. Hexagonocaulon minutum gen. et sp. nov. 2·2mm x 1·3mm in diameter. Slide Number 23, Specimen Number P.224.25
E. Hexagonocaulon minutum gen. et sp. nov. 1·8mm. in diameter. Slide Number 24, Specimen Number P.224.29
F. Hexagonocaulon minutum gen. et sp. nov. 1·7mm. in diameter. Slide Number 14, Specimen Number P.224.27




Text Figure 38: A. Hexagonocaulon minutum gen. et sp. nov. Complete specimen with stele, measuring 3·15mm. in diameter. Slide Number 25, Specimen Number P.224.25

B. Hexagonocaulon minutum gen. et sp. nov. 3·9mm. in diameter. Slide Number 10, Specimen Number P.224.21

From the evidence obtained, it is unknown whether the scale leaves may have been fleshy in life and had a photosynthetic function (either on a temporary or permanent basis) or were, in fact, scale-like and possibly used as an aid in support within other vegetation.

The differentiation of the stele is very difficult to interpret as the phloem does not seem to have been preserved and in several slides areas of broken-down cells occur on the outer points of the stele, possibly marking the position of the protoxylem, suggesting that the xylem was exarch. The stele appears to have short leaf gaps as they do not overlap when present but it is impossible to say whether the phloem developed on the outside or on both sides of the xylem as in medullated protosteles and siphonosteles or solenosteles respectively.

The axes do not compare with any of the Bryopsida or the solid protostelic Psilophytopsida, but it does bear a superficial resemblance to the Psilotopsida. Psilotum possesses an overall similar shape in its aerial branches, has a hexagonal stele with exarch protoxylem and in the smaller underground axes (less than 1·0 millimetre in diameter) a stele does not develop and the space is filled with parenchyma.

Tmesipteris is much less like the axes described and the Lycopsids, which have spirally arranged leaves and no leaf gaps show no close comparison.

The Sphenopsids and in particular the Equisetites compare very well with the present material and have several features in common. In the Equisetites there is a monopodial branch system; nodal diaphragms are present; the internodes of aerial stems is made up of large air spaces; in subterranean axes a stele does not develop and is replaced by pith; the xylem has annular and helical thickenings and the whorled scale leaves are fused in a sheath and in multiples of three. (from Sporne, 1974

In contrast, Equisetites has a medullated protostele with endarch pro xylem and a xylem ring in the diaphragm which gives off leaf traces.

It is possible that the hollow, hexagonal stele had a central medulla which has not preserved and that the material identified as exarch protoxylem was in fact phloem and endarch protoxylem (carinal canal) was not preserved.

The specimens do not compare with Pteropsids, Cycadopsids or Coniferopsids, although they do exhibit superficial resemblances to transverse sections of Vertebraria indica.

In the Gnetopsida, the axes bear a striking similarity to the small leafy shoots of Ephedra.

Chamberlain (page 366, 1957) states that the leaves of the American species of Ephedra are usually in whorls of three and in all cases the whorls alternate.

Sporne (1974b) states that the leaves are reduced to minute scales which are soon shed and photosynthesis is carried out by the ribbed stems (this would account for the large numbers of axes present lacking leaf sheaths which were found in the collection).

The leaf trace is made up of two traces which arise from a single gap (two trace - unilacunar) and the secondary wood is made up of poorly differentiated fibres, vessels and ray parenchyma (Esau, 1965).

Bierhorst (1971) states that similarities between Ephedra and Equisetum extend beyond the jointed stem with intercalary growth and reduced, whorled and fused leaves. In each the leaf traces extend throughout an entire internode and in the Equisetum stems below those points where the leaf traces are double, the stele is essentially identical to that of Ephedra. The similarity extends also to the metaxylem girdle at each node.

Ephedra pollen grains have been described from Permian (Wilson, 1959) and Upper Triassic deposits (Scott, 1960) but little is known of the macrofossil vegetative remains.

From studies on Ephedra, it was noted that during sectioning of small aerial axes, the parenchymatous pith was very delicate and often pulled apart and that there was a small gap between the stelar and outer tissues which caused the stele to drop out in several sections. This delicate pith and cortex would probably not be preserved in fossil material.

It was also noted that helical thickening was apparent in the stem and leaf trace protoxylem.

In conclusion, these hexapartite axes have much in common with both Ephedra and Equisetites, less with Psilotum and Tmesipteris and much less with Vertebraria.

In view of the uncertainty of identification, it is proposed to name these axes Hexagonocaulon minutum gen. et sp. nov. (ie. very small six angled stem) until more evidence relating to their affinity can be obtained.

Diagnosis: Small, slender axes at least 10mm. long, 0·5 - 4·0mm. wide with internodes 2 - 4mm. long, composed of one or sometimes two six sided or lobed concentric layers of tissue, bearing alternating whorls of three bi-lobed or flanged scale-like leaves. Hollow, hexagonal shaped stele with annular or helical ? thickened tracheids and connected with the outer surrounding tissue at the nodes ? by parenchymatous diaphragm 2 - 4 cells in thickness. The reproductive organs are unknown.

## Axis (indeterminate)

(Plate 13:50)

The axis measures 1·4 millimetres by 1·3 millimetres in diameter and has two to three outer layers surrounding a single compressed inner layer of cells. The thick celled outer layers have similarities with the corresponding layers in certain sections of Hexagonocaulon minutum gen. et sp. nov. (see Plate 12:46) and the inner layer is similar to compressed axes of Equisetites sp. (see Plates 5:18 and 5:19).

It is interesting to speculate that this could be the missing link connecting the mainly subterranean and rhizomatous specimens of Equisetites sp. with the many aerial axes of Hexagonocaulon minutum.?

## Axis (indeterminate)

(Plate 13:51)

This axis measures 2·2 centimetres by 1·8 centimetres in diameter and although incomplete, reveals part of the outline of a C shaped trace.

This axis may be equivalent to more complete and better preserved forms which possess a C shaped stele and have been included in Asterotheca crassa (compare with Text Figure 19:E).

## Branched axis (indeterminate)

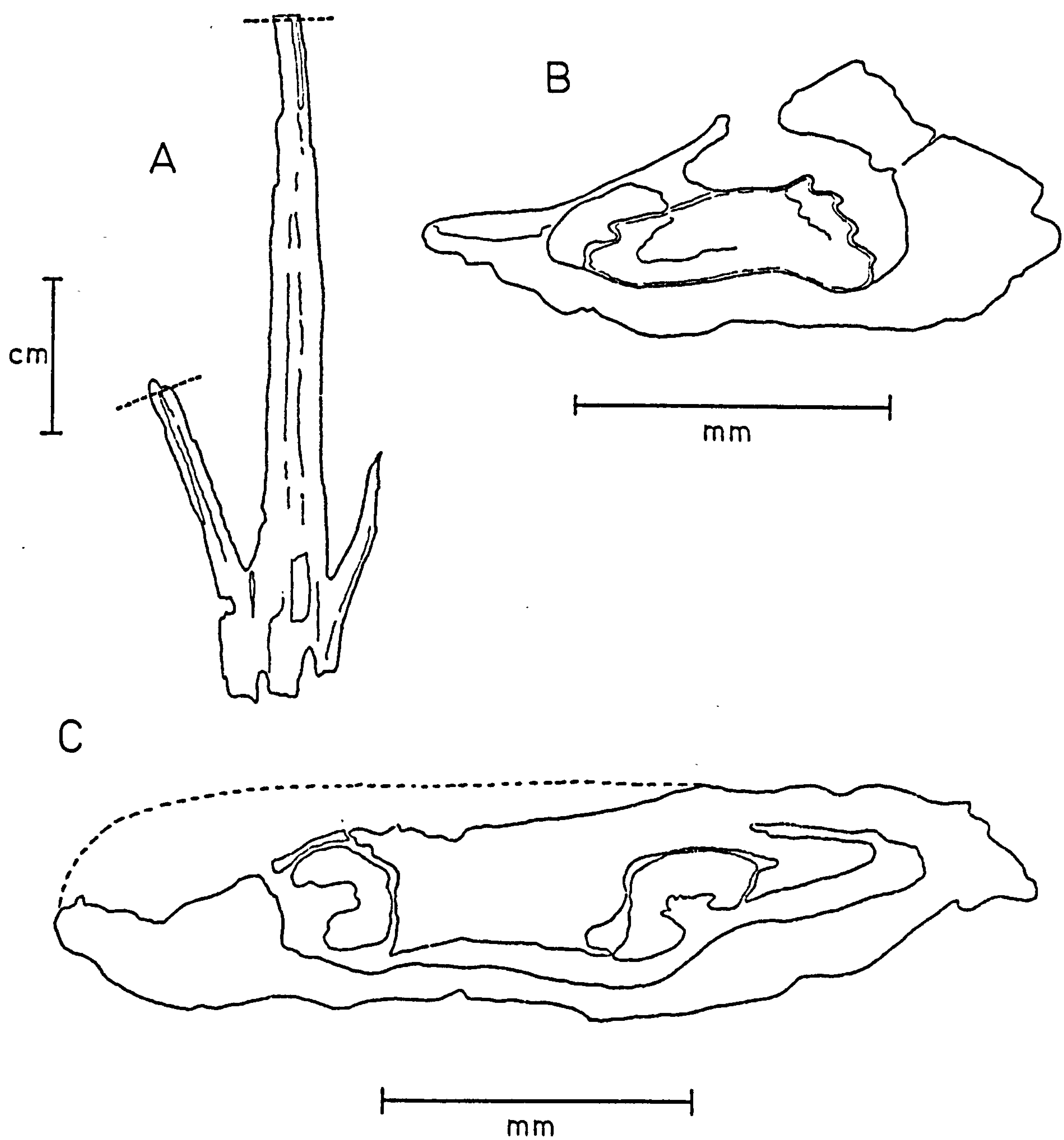
(Text Figure 39)

This axis was first described by Orlando (1968) as an impression of either a Pteridophyte or Pteridosperm stem but not figured.

I have succeeded in making peel sections of both the main axis and the larger branch and these reveal a distorted C shaped anatomy.

This indicates that the axis is of undoubted Pteridophyte affinity. Asterotheca crassa has already been described from this collection possessing a similar anatomy, including the rachis described by Orlando (1968) as Osmundaceous.

The anatomy of this material compares very well to that in axes of




Text Figure 39: A. Pteridophyte axis. 4·5cm. long x 1·5cm. wide. Hobbs Specimen Number P.101.5
B. Pteridophyte axis. Branch section. 2·0mm. x 0·9mm. in diameter. Hobbs Specimen Number P.101.5
C. Pteridophyte axis. Main axis section. 3·2mm. x 0·75mm. in diameter. Hobbs Specimen Number P.101.5

*Asterotheca crassa* (compare Text Figures 39:B with 19:B, D & F).

From this evidence it would appear that this branched axis belonged to *Asterotheca crassa*. The main axis section (Text Figure 39:C) shows better comparisons with Text Figure 19:C as in both cases the stele is slightly more complicated, although the axes have been compressed in opposite directions. This evidence further supports the belief that the axis described by Orlando (1968) as a rachis of Osmundaceae is in fact part of *Asterotheca crassa*.

## Leaf (indeterminate)

(Text Figure 40:A)

Impression of a leaf, 3·75 centimetres long by 2·0 centimetres wide with a prominent midrib approximately 0·9 millimetres thick. No venation is preserved.

## Leaf (cf. Phoenicopsis - Ginkgoites type)

(Text Figure 40:B)

Leaf measuring 4·3 centimetres long by 1·5 centimetres wide with a prominent midrib up to 1·4 millimetres thick extending from the petiole and apparently dividing up into three equally broad veins in the lamina. It is possible that the veins are caused by folds or creases in the blade or are composed of a conglomeration of finer veins.

## Leaf (cf. Dipteridaceae type)

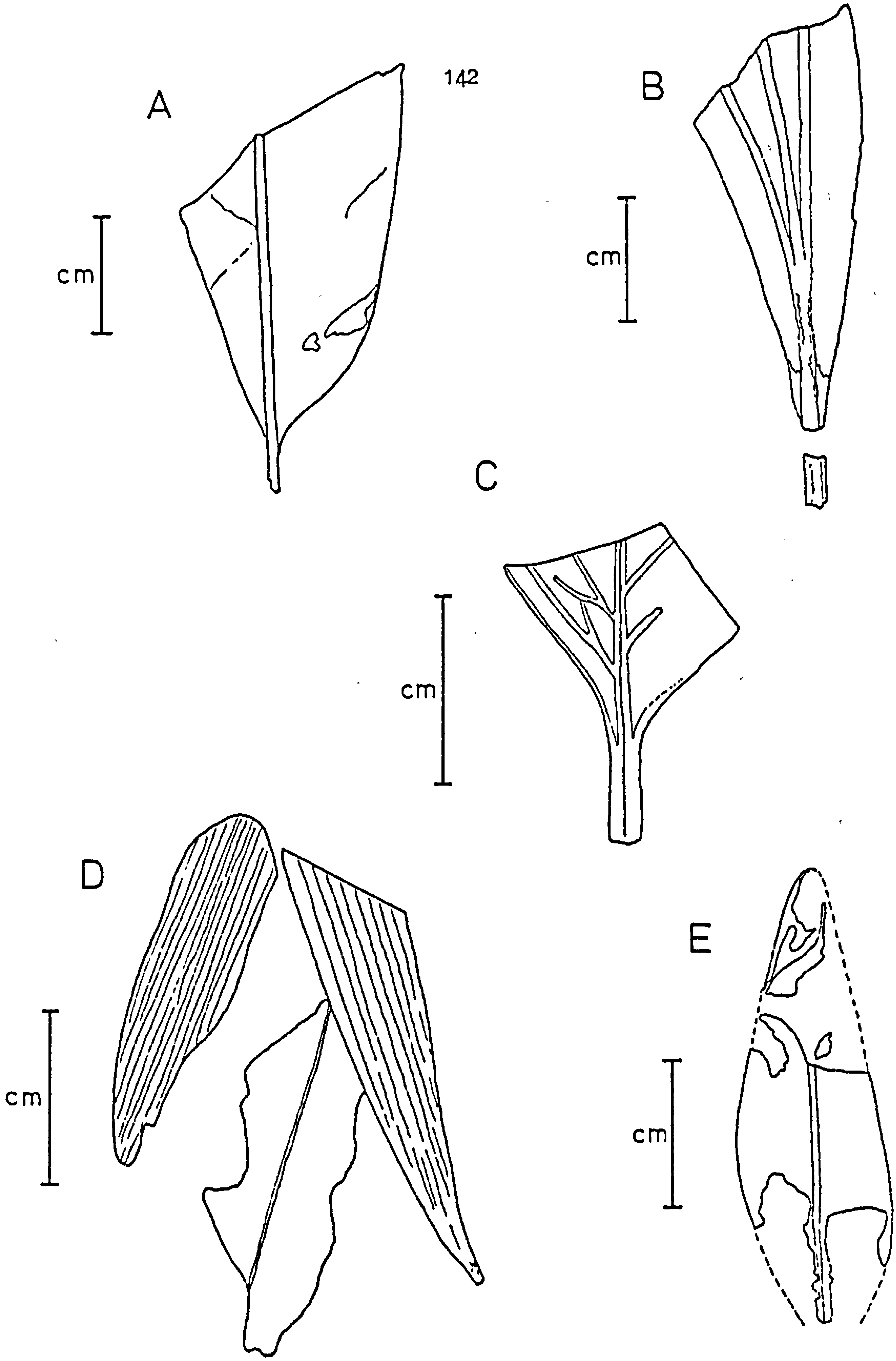
(Text Figure 40:C)

Leaf measures 1·6 centimetres long by 1·2 centimetres wide with a thick, tapering midrib approximately 0·75 millimetres broad. After emerging from the petiole the midrib gives off two marginal veins and the remaining major vein bears alternating dichotomous secondary venation.

## Leaves (indeterminate, cf. Phoenicopsis - Sphenobaiera type)

(Text Figure 40:D)

Impressions of three leaves, one measuring 2·1 centimetres long by




Text Figure 40: A. Leaf (indeterminate). 3·75cm. long x 2·0cm. wide. Specimen Number P.426.8

B. Leaf (cf. Phoenicopsis - Ginkgoites type). 4·3cm. long x 1·5cm. wide. Specimen Number P.426.4

C. Leaf (cf. Dipteridaceae type). 1·6cm. long x 1·2cm. wide. Specimen Number P.426.10

D. Leaves (indeterminate, cf. Phoenicopsis - Sphenobaiera type). 2·1cm. long x 0·8cm. wide, 2·2cm. and 2·8cm. long x 0·54cm. and 0·58cm. wide respectfully. Specimen Number P.426.12

E. Leaf (indeterminate). 3·2cm. long x 1·15cm. wide. Specimen Number P.224.7

0•8 centimetres wide with a fine prominent midrib 0•3 millimetres thick but without the secondary venation preserved and hence indeterminate.

The remaining two leaves, 2•2 and 2•8 centimetres long and 0•54 and 0•58 centimetres wide respectfully have fine parallel venation traversing the lamina and although the number of veins increased with the width of the lamina, no dichotomies were observed.

Leaf (indeterminate)

(Text Figure 40:E)

Fragments of a very poorly preserved leaf, measuring 3•2 centimetres long by over 1•15 centimetres wide with a prominent midrib approximately 0•5 millimetres thick. The leaf appears to have undergone some damage or was possibly partially decomposed prior to fossilization.

Wood (indeterminate)

(not illustrated)

Small fragment of coalified, compressed wood which in section revealed rays 4 - 7 cells high (105μm - 290μm) but no other details. Slide number 27, Hobbs specimen number P.101.2.

## MICROFOSSILS

### Microfossils recognized in peels

(Plates 14:52 - 55, Text Figure 41:A)

From a series of peel sections made transversely through an axis of Hexagonocaulon minutum gen. et sp. nov. several 'spore clusters' were found to have been preserved inside the axis and in some cases these had broken up leaving groups of individual spores (refer to Plate 12:46 and Text Figure 38:B). These same spores were also found in the surrounding matrix and often mixed with thin filaments but never in organic connection.

Similar spores were recognized in a second axis preserved close to the first but these were less well preserved and no clusters could be seen.

The clusters measure between 70µm - 84µm by 154µm - 187µm in diameter and the individual spores range between 7µm - 60+µm. The filamentous strands were up to 10µm thick and up to 500µm long, with apparent broken ends. All of these measurements were made from peel 6, slide number 11.

Plates 14:52 and 14:53 illustrate the detail that can be observed in one of the better preserved spore clusters which, from serial sections appear to be spherical in shape (see also Text Figure 41:A).

Plate 14:54 shows the mixture of spores and filaments found in the matrix and Plate 14:55 reveals the furry-like surface texture of the spores.

Identification of these bodies has proved very difficult. It is possible that they may have been fungal in origin and entered the plant body before death (endophytic or parasitic), after death (saprophytic) or entered passively, suspended in the sediments during the process of fossilization. There seems no evidence to support either of the first two possibilities as there does not seem to have been any host reaction or breakdown of tissues.

The material has been examined by mycologists in the School of Plant Biology at U.C.N.W. and they reject it as being of fungal origin.

It is possible that these are some kind of reproductive spores produced by a higher plant (not necessarily by Hexagonocaulon minutum) and became trapped during fossilization.

From the histogram of spore size made up from the measurements of over two hundred spores (refer to Text Figure 42), it is evident that although the spores range in size from less than 10µm to over 60µm a peak occurs with the 10µm - 14·9µm group. This makes the curve very much skewed to the left as would be the case if many of the spores were immature.

Homosporous spores have been recorded from Equisetum X moorei which range in size from less than 10µm to greater than 65µm, although each spore is always in intimate association with an elater (Duckett, 1970).

A third possibility is that these spores represent nothing more than storage material, tannin or resin bodies. This would appear to be unlikely and could not account for their abundance in the surrounding matrix.

Microfossils isolated by bulk maceration

(Text Figure 41:B - J)

In total, eight types of spore-like or algal bodies and two cuticles were extracted by bulk maceration. These microfossils may be sub-divided into bi-lobed and spherical types.

Bi-lobed types (Desmidiodeae)

(Text Figure 41:B and C)

The placoderm desmids are much more numerous than the saccoderm and are an important constituent of phytoplankton.

Typically, each cell is divided into two halves, one being the mirror image of the other and connected by a narrow central portion, the isthmus.

The cell wall is made up of an inner cellulose layer and an outer layer of variable composition, frequently containing iron compounds or silica. Within the cell, the nucleus usually lies in the isthmus with one or more chloroplasts in each half-cell.

All of these characters occur in the two bi-lobed fossils described.

Text Figure 41:B This is the smaller of the two bi-lobed microfossils and measures 32µm by 25µm in diameter. The surface appears slightly knobbly and inside the cell there occurs the remains of the protoplast. This too is bi-lobed in shape and each of the lobes has a darkened central area.

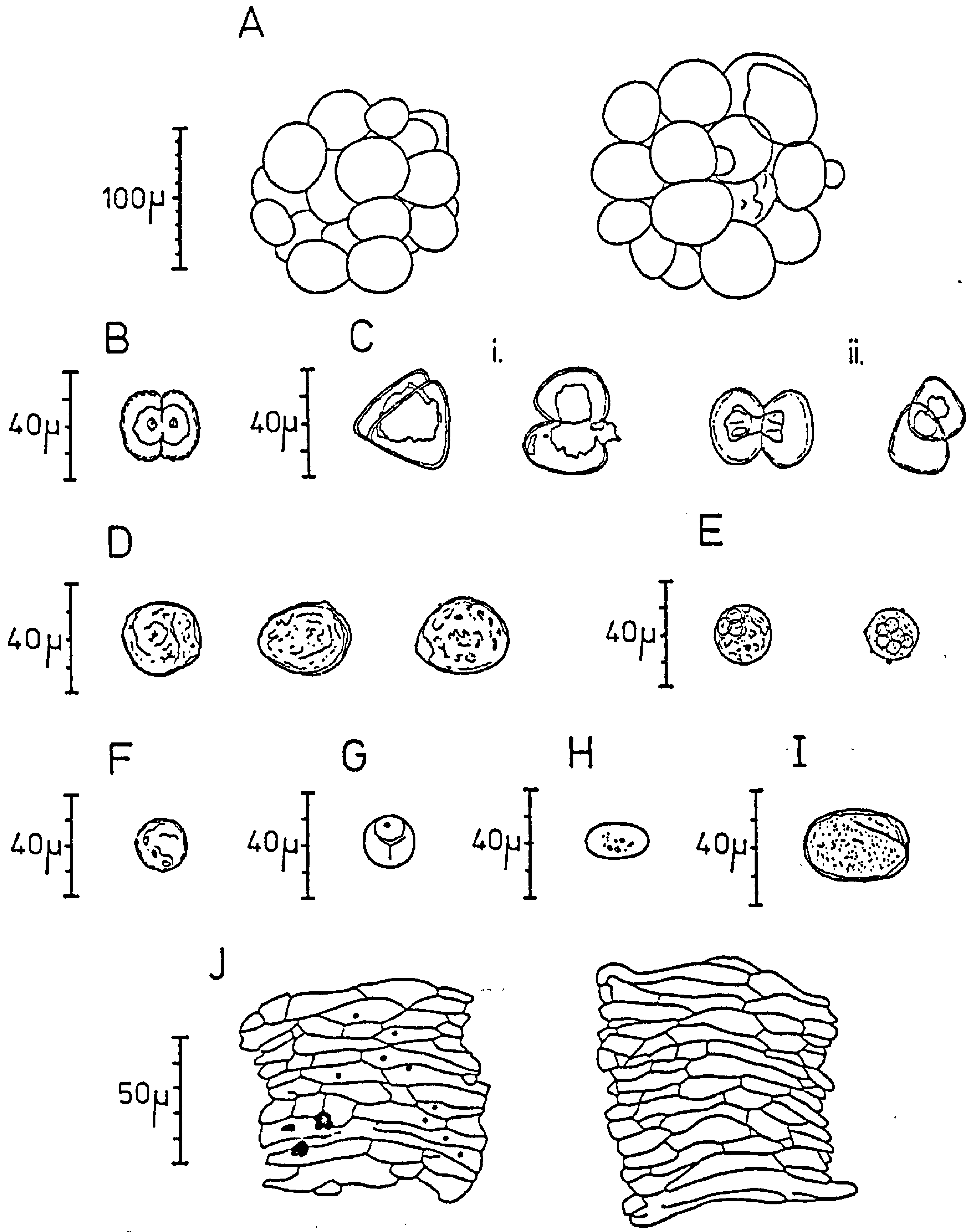
Text Figure 41:C Two specimens are shown (i and ii) and illustrate the specimens from different angles. In both cases they appear triangular in shape when viewed 'end on' but appear rounder and dumb-bell shaped when viewed 'side on', measuring up to 40µm long by 28µm - 33µm in diameter. As with the previous specimen, both contain bi-lobed central tissue.

## Spherical types

Text Figure 41:D Three specimens were found and all oblate spheroid in shape with a rough textured outer surface, measuring 35µm by 28µm in diameter on average. No comparisons could be found.

Text Figure 41:E Two specimens, both spherical, measuring 19µm and 23µm in diameter with a rough textured surface were recognized in the sample. Both specimens contained what appeared to be smaller sphere-like objects and the smaller microfossil had what resembled short protuberances covering part of the outer layer.

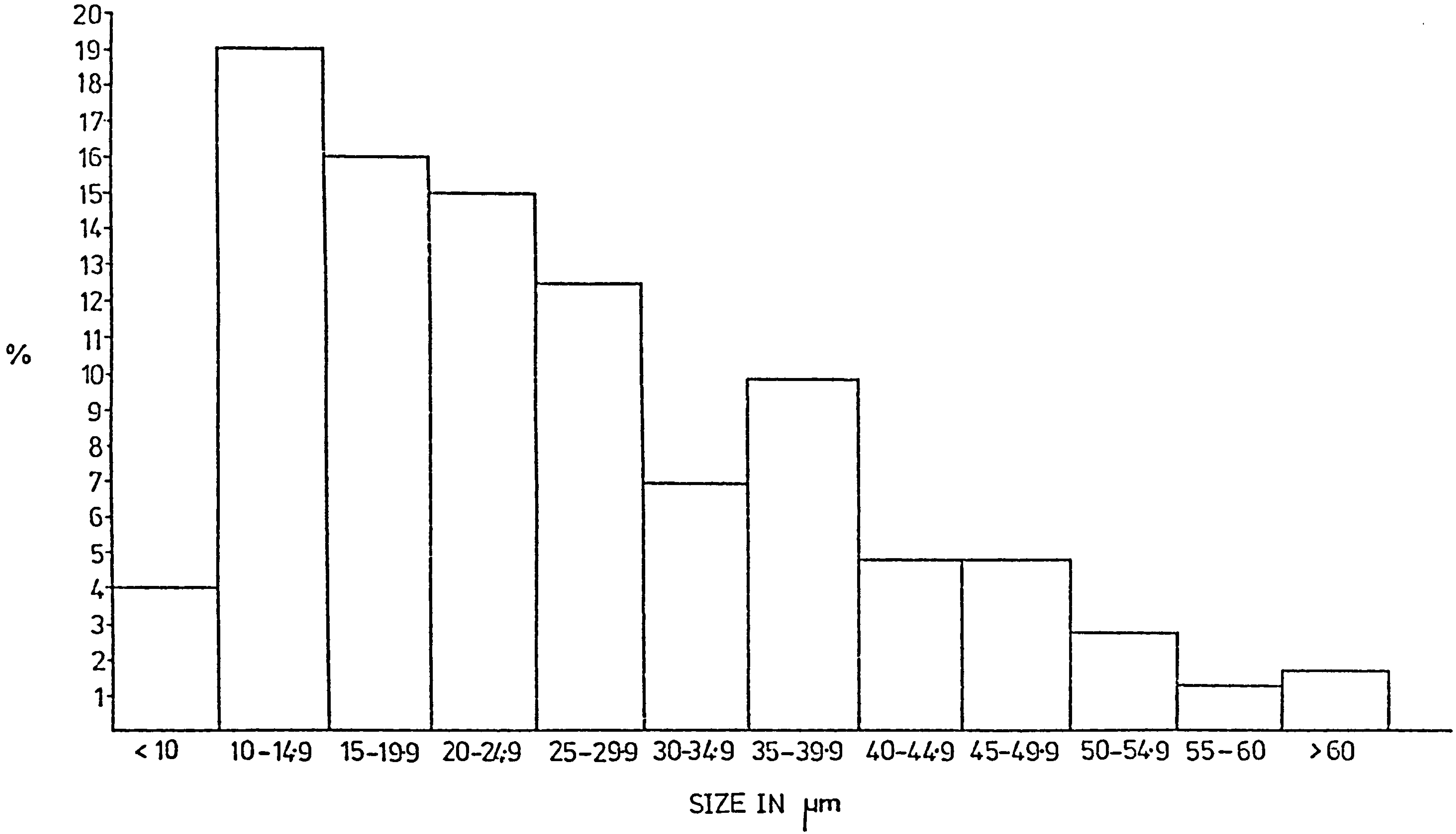
These knobbly spores compare in some respects with microspores from extant heterosporous lycopods such as Selaginella (Moore and Webb, 1978), although the inner small spheres could be more indicative of an algal affinity (ie. some kind of resting spore).




Text Figure 41: A. Spore clusters. 150µm x 150µm and 180µm x 175µm in diameter. Slide No. 11. Specimen Number P.224.21

B - I. Assorted microfossils. Specimen Numbers P.224.21 and P.224.27

J. Cuticles. 90µm x 86µm and 102µm x 104µm in diameter. Specimen Numbers P.224.21 and P.224.27




Text Figure 42: Histogram of spore size found in association with <u>Hexagonocaulon</u> <u>minutum</u> gen. et sp. nov.

Text Figure 41:F Single spore, 21μm in diameter with a slightly scarred but otherwise fairly smooth surface (indeterminate).

Text Figure 41:G Single spore, 19•5μm in diameter with a smooth surface and possible tri-radiate scar. A small dark mass was discernible to one side of the spore. It bears a resemblance to spores of Sphagnum (Moore and Webb, 1978).

Text Figure 41:H Single spore, ovoid in shape, measuring 23•5μm by 14μm in diameter with a fairly smooth surface (indeterminate).

Text Figure 41:I Large single spore measuring 36•5μm by 25•5μm in diameter with a pitted outer layer exhibiting two opposite longitudinal grooves. It compares in some respects to spores of Pteridium (Moore and Webb, 1978).

These microfossils have been compared with established spores and algae known from the Triassic period (Chaloner, 1969 and Evitt, 1969) but the comparisons have met with little success.

## Cuticle remains

The remains of two cuticles were obtained during the course of bulk maceration for spores (refer to Text Figure 41:J). The cuticles are very small, measuring 90μm by 86μm and 104μm by 102μm in size and in the smaller fragment, the position of some of the nuclei or possibly root hair bases have been preserved.

It is impossible to establish from which plant these cuticles may have originated, but it is likely that they belong to the very small axes of Equisetites sp. which are abundant in the collection.

## DISCUSSION

The following lists are of taxa recognized from the three sub-collections from Williams Point, Livingston Island as described in chapter two of this Thesis. Those species marked with an asterisk indicate a new record for the locality.

Collection P.224.2 - P.224.16b

* cf. Equisetites sp.

* cf. Dicroidium (Xylopteris) spinifolia (Frenguelli) Archangelsky

Axes (indeterminate)

Collection P.224.17 - P.224.55

* Thallites sp. (type a)

* Thallites sp. (type b)

* Equisetites sp.

cf. Asterotheca crassa Orlando

* Dicroidium cf. lancifolium (Morris) Gothan

* Dicroidium (Xylopteris) cf. spinifolia (Frenguelli) Archangelsky

* Pagiophyllum sp.

* Ginkgoites sp.

* Doratophyllum (Taeniopteris) tenison-woodsi (Etheridge) Harris

* Hexagonocaulon minutum gen. et sp. nov.

* Microfossils (including Desmidioideae)

Collection P.426

* Neocalamites sp.

* Equisetites sp.

cf. Asterotheca crassa Orlando

* Pterophyllum dentatum sp. nov.

There is nothing to suggest that these collections came from significantly different horizons and as such will be treated as a complete flora. The complete flora includes all species determined by Orlando (1968) and those found by a re-examination of this original collection.

<u>Complete fossil flora</u>

*Thallites* sp. (type a)

*Thallites* sp. (type b)

o *Equisetites* sp.

*Neocalamites* sp.

o– *Asterotheca crassa* Orlando

– *Coniopteris distans* Orlando

– Rachis of Osmundaceae (*Asterotheca crassa*)

– Frond of Dipteridaceae

– *Thinnfeldia* (*Dicroidium* sp.)

*Dicroidium* cf. *lancifolium* (Morris) Gothan

– *Dicroidium* (*Xylopteris*) cf. *elongata* (Frenguelli) Archangelsky

*Dicroidium* (*Xylopteris*) cf. *spinifolia* (Frenguelli) Archangelsky

*Pterophyllum dentatum* sp. nov.

o *Pagiophyllum* sp.

o *Ginkgoites* sp.

*Doratophyllum* (*Taeniopteris*) *tenison-woodsi* (Etheridge) Harris

o *Hexagonocaulon minutum* gen. et sp. nov.

Macrofossils (indeterminate, cf. *Phoenicopsis* – *Sphenobaiera* types)

• Wood (indeterminate)

Microfossils (including Desmidioideae)

<u>Key to symbols:</u> – recorded by Orlando (1968) from Hobbs 1959 collection;

o recorded in both collections, after re-examination of the 1959 material

• recorded in 1959 material only, after re-examination of Hobbs collectic

## COMPOSITION

The flora is dominated by 'in situ' remains (Equisetites sp., Hexagonocaulon minutum) and to a lesser extent by drifted fragmental conifer shoots.

Pteropsids are much less abundant and are again of a very fragmented nature.

All of the other taxa are rarer and often restricted to single rock specimens.

Reproductive organs are rare and indeed have not been identified with any certainty and seeds entirely absent.

Several types of microfossil are present, although only those representing unicellular algae (desmids) have been identified with any certainty.

## COMPARISONS WITH OTHER FLORAS FROM ANTARCTICA

(refer to Table 11)

Very few floras of Triassic age have been found in Antarctica and as the majority of these are small, they contain a restricted number of taxa which necessarily makes worthwhile comparisons more difficult.

At present, only three other reasonable sized floras have been described apart from the earlier Livingston Island collection.

These are from the Upper Taylor Glacier (Plumstead, 1962) and from Mount Bumstead and Allan Nunatak (Grindley et al, 1964 and Townrow, 1967).

The best comparison can be made with the flora from Mount Bumstead which has three taxa in common.

## COMPARISONS WITH OTHER FLORAS FROM THE REST OF GONDWANALAND

(refer to Table 12)

Africa: The flora compares with the Molteno of South Africa (Du Toit, 1927 and Anderson, 1974, 1976); the Upper Beaufort of South Africa

| | Upper Taylor Glacier Ross Sea Area — Plumstead (1962) | Mount Bumstead (head of Mill Glacier) — Grindley et al (1964) Townrow (1967a) | Shackleton Glacier — Grindley et al (1964) Townrow (1967a) | Allan Nunatak Victoria Land — Townrow (1967a) | Williams Point Livingston Island — Orlando (1968) |
|---|---|---|---|---|---|
| Thallites | | | | | |
| Equisetites | | | | | |
| Neocalamites | ● | | | | |
| Asterotheca | | | | | ● |
| Coniopteris | | | | | ● |
| Dipteridaceae | | | | | ● |
| Dicroidium lancifolium | | | | | |
| Dicroidium elongata | | ● | | ● | ● |
| Dicroidium spinifolia | | | | | |
| Pterophyllum | | | | | |
| Conifer shoots (Pagiophyllum) | | ● | | | |
| Ginkgoites | | ● | | | |
| Doratophyllum tenison-woodsi | | | | | |

Table 11. Comparison with other floras from Antarctica

● = taxa in common.

| | Thallites | Equisetites | Neocalamites | Asterotheca | Coniopteris | Dipteridaceae | Dicroidium lancifolium | Dicroidium elongata | Dicroidium spinifolia | Pterophyllum | Conifer shoots (Pagiophyllum) | Ginkgoites | Doratophyllum tenison-woodsi | ● = taxa in common. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Molteno, S. Africa | ● | ● | ● | ● | | ● | ● | ● | ● | ● | ● | ● | | Anderson (1974, 1976) |
| U. Beaufort, S. Africa | | ● | ● | | | | ● | ● | | ● | | ● | | Du Toit (1927) |
| Molteno, Rhodesia | | | | | | | ● | ● | | ● | ● | ● | | Lacey (1970, 1976) |
| U. Karroo, Zambia | | | ● | | | | | | | | | | | Lacey & Smith (1972)<br>Lacey & Lucas (in press) |
| | | | | | | | | | | | | | | |
| Wianamatta, N.S.W. | | | | | | | ● | | | | | | | Retallack (1977a) |
| Hawkesbury, N.S.W. | | | | | | | | | | | | | | Retallack (1977a) |
| Narrabeen, N.S.W. | | | | | ● | | ● | | | | ● | | ● | Burgess (1935), Walkom (1925 |
| Red Cliffs, N.S.W. | | | | | | | | ● | | ● | | ● | | Flint & Gould (1975) |
| Nymboida, N.S.W. | | | | | | | ● | | | | ● | | | Flint & Gould (1975) |
| Gunnee, N.S.W. | | | | ● | | | ● | ● | | | ● | ● | | Bourke et al (1977) |
| Ipswich, Queensland | | ● | ● | | | ● | ● | ● | ● | ● | | ● | ● | Jones & de Jersey (1947) |
| Esk, Queensland | | | ● | ● | ● | | | | | ● | ● | ● | | Rigby (1977)<br>Walkom (1915,1917a & b,1918 |
| B. Marsh, Victoria | | | | | | | ● | ● | | | | ● | | Chapman (1927),Douglas (1969 |
| Tasmania | | | ● | | | | | | | | | ● | | Jain & Delevoryas (1967) |
| | | | | | | | | | | | | | | |
| Ischigualasto, Argent. | | ● | ● | ● | | | ● | ● | ● | | | ● | | |
| Marayes, Argentina | | ● | ● | | ● | ● | ● | ● | ● | ● | ● | | | Archangelsky (1965, 1968) |
| Potrer.-Cacheuta, Argen | ● | ● | ● | ● | | | ● | ● | | | | | | Arrondo (1972) |
| Barreal, Argentina | | | ● | | | | ● | ● | | | | | | Frenguelli (1948) |
| Llantenes, Argentina | | ● | | | | | ● | ● | | | | | | Jain & Delevoryas (1967) |
| Paso Flores, Argentina | | | | | | | ● | | | | | ● | | |
| Vilos-Ternera, Chile | | ● | | ● | | | ● | | | ● | | | | Archangelsky (1968) |
| Santa Maria, Brazil | | | ● | | | | ● | | | | | | | Archangelsky (1968) |
| | | | | | | | | | | | | | | |
| Maleri, India | | | ● | | | | | | | | | ● | | Lele (1976) |
| Pachmarhi, India | | | | | | | | | | ● | | | | Maheshwari (1976) |
| Panchet, India | | | | | | | | | | | | | | Sitholey (1954) |
| | | | | | | | | | | | | | | |
| L. Mesozoic, N. Zealand | | | | | | ● | ● | | | | ● | | | Arber (1917) |

Table 12. Comparison with other floras from the rest of Gondwanaland

(Du Toit, 1927) and to a lesser extent with the Upper Karroo of Zambia (Lacey and Smith, 1972 and Lacey and Lucas, in press).

Australia: The flora compares with the Esk Formation (Walkom, 1915, 1917a, 1917b, 1918 and Rigby, 1977) and Ipswich Coal Measures (Jones and De Jersey, 1947) of Queensland; the Basin Creek and Cloughers Creek floras (Flint and Gould, 1975 and Retallack et al, 1977) which make up the Nymboida deposits; the Red Cliffs flora (Flint and Gould, 1975) and the Gunnee Beds flora (Bourke et al, 1977) of New South Wales and to a lesser extent with the Bacchus Marsh flora (Chapman, 1927 and Douglas, 1969) of Victoria.

South America: The flora compares with the Llantenes and Potrerillos - Cacheuta Formations of Mendoza and with the Barreal, Ischigualasto and Marayes Formations of San Juan (Archangelsky, 1965 and 1968, Jain and Delevoryas, 1967 and Arrondo, 1972) in Argentina and to a lesser extent with the Los Vilos and La Ternera floras of Chile and the Santa Maria flora of Brazil (Archangelsky, 1968).

India: The Indian Middle Gondwana is rather poorly represented but of the three stages; Panchet, Pachmarhi and Maleri, the latter stage would appear to have the most in common (Sitholey, 1954; Lele, 1976 and Maheshwari, 1976).

New Zealand: The flora compares superficially with the Lower Mesozoic of New Zealand (Arber, 1917).

## AGE

(refer to Table 13)

The collection is of undoubted Triassic age and contains many species which are characteristic of the Lower Mesozoic and relics from the Permian period are rare.

Dicroidium spp. are very indicative of a Triassic age and Retallack (1977b) states that Dicroidium lancifolium is restricted between the

<table>
<tr><th>PM.</th><th colspan="5">L. TRIASSIC</th><th colspan="5">M. TRIASSIC</th><th colspan="6">U. TRIASSIC</th><th>JURS.</th><th></th></tr>
<tr><th>U. Permian</th><th>L. Griebachian</th><th>U. Griebachian</th><th>Dienerian</th><th>Smithian</th><th>Spathian</th><th>L. Anisian</th><th>M. Anisian</th><th>U. Anisian</th><th>L. Ladinian</th><th>U. Ladinian</th><th>L. Carnian</th><th>U. Carnian</th><th>L. Norian</th><th>M. Norian</th><th>U. Norian</th><th>Rhaetian</th><th>Lower Jurassic</th><th></th></tr>
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<tr><td colspan="8"></td><td colspan="6">Upper Karroo<br>(1)</td><td colspan="4"></td><td>Zambia</td></tr>
<tr><td colspan="6">Narrabeen<br>(4)</td><td colspan="2">Hawks.<br>(0)</td><td colspan="2">Wiana.<br>(1)</td><td colspan="8"></td><td>N.S.W.</td></tr>
<tr><td colspan="7"></td><td colspan="4">Nymboida<br>(2)</td><td colspan="5">Red Cliffs<br>(3)</td><td colspan="2"></td><td>N.S.W.</td></tr>
<tr><td colspan="7"></td><td colspan="3">Gunnee<br>(5)</td><td colspan="8"></td><td>N.S.W.</td></tr>
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<tr><td colspan="11"></td><td colspan="2">Maray.<br>(9)</td><td colspan="5"></td><td>Argentina</td></tr>
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<tr><td colspan="7"></td><td colspan="4">Barreal<br>(3)</td><td colspan="7"></td><td>Argentina</td></tr>
<tr><td colspan="14"></td><td colspan="3">Llant.<br>(3)</td><td></td><td>Argentina</td></tr>
<tr><td colspan="15"></td><td colspan="2">P.Flor.<br>(2)</td><td></td><td>Argentina</td></tr>
<tr><td></td><td colspan="5">Panchet<br>(0)</td><td colspan="5">Pachmari<br>(1)</td><td colspan="5">Maleri<br>(2)</td><td colspan="2"></td><td>India</td></tr>
</table>

Table 13. Stratigraphic correlation of Middle Gondwana floras. (Number of common taxa shown in brackets).

Smithian and Rhaetian and that Dicroidium (Xylopteris) spinifolia is restricted between the Anisian and Norian.

Stipanicic and Bonetti (1967) state that Dicroidium (Xylopteris) elongata and Dicroidium (Xylopteris) spinifolia are common elements in the Mid - Upper Triassic of Argentina.

Orlando (1968) states that Coniopteris is a common member of the Mid Triassic of Argentina.

The flora has many elements in common with both the Esk (upper Anisian - upper Ladinian) and younger Ipswich (upper Ladinian - lower Norian) floras from Australia and with the Molteno (upper Anisian - lower Norian) flora of Africa.

From a study of the oppel-zones (defined as an evolutionary change of fossil plants and fossil plant associations with time) put forward by Retallack (1977a), the flora has more in common with the Dicroidium odontopteroides oppel-zone (Aniso - Ladinian) than with the earlier Dicroidium zuberi oppel-zone (Smithian - Anisian) or the later Yabeiella oppel-zone (Ladino - Carnian).

From all accounts, the flora would appear to range from mid to upper Anisian to mid Norian and probably occupies a central position in the range (Ladino - Carnian) as it appears to have a similar number of taxa in common with both the earlier (Aniso - Ladinian) and later (Carno - Norian) floras.

This age (upper Mid Triassic - lower Upper Triassic) for the flora is younger than the Lower - Mid Triassic age determination of Orlando (1968).

## ENVIRONMENT

The Bryopsida ? (3.5 %) and the Sphenopsida (50 %) are all preserved in situ and the latter group form the most dominant members of the collection. The remaining Pteropsida (6 %), Cycadopsida (4 %), Coniferopsida

(25 %) and Incertae Sedis (11·5 %) make up the rest and apart from Hexagonocaulon minutum, are all preserved in a very fragmented condition.

In Situ plants: Both Thallites spp. appear to be sterile (apart from the small bumps found adjacent to the midrib in Thallites sp. b. which may possibly represent involucres) and this is often indicative of favourable growing conditions. The plants themselves are reasonably undamaged and suggests they were preserved in the place of actual growth on mud banks or if transported, were carried only a short distance.

Both Equisetites sp. and Hexagonocaulon minutum were preserved in situ and indicate that the sedimentary rock in which these remains are found also represents part of the original habitat and which must have undergone periodic inundation at some time. Much of the matrix is made up of fine silt and mudstones which suggest transportation was by slow moving streams, an idea further supported by the fragmented plant remains which are all small (and hence would be light) and fairly easily transported by sluggish moving water.

Fragmentary plants: These no doubt represent the flora which grew some distance from the sedimentary basin and were brought in to the site. No large heavy twigs, wood fragments or seeds have been found in the collection and probably indicate that these would have been sorted out and deposited further upstream.

The remains are dominated by coniferopsids, showing that these were either easily transported, preserved better or were a dominant constituent of the hinterland vegetation. This latter point has not been substantiated by microfossil studies, ie. no coniferous pollen has yet been identified.

Microfossils: Fossil desmids have been recognized and these are very indicative of a lacustrine type of environment.

It is extremely difficult, if not impossible to obtain reliable quantitative information on the composition of fossil plant associations, since a single collection, however large, is likely to be affected by natural sorting and may not represent an accurate cross section of the flora as a whole.

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PLATE 4

Plate 4·13 *Thallites* sp. (type a). 3-4mm. wide and up to 2·0cm. in length.
Specimen Number P.224.21

Plate 4·14 *Thallites* sp. (type a). High power of dichotomy seen in plate 4·13 (under xylol).
Specimen Number P.224.21

Plate 4·15 *Thallites* sp. (type b). 2mm. wide x 2·2cm. long.
Specimen Number P.224.21

Plate 4·16 *Neocalamites* sp. From top to bottom, axes measure 3·1cm. long x 1·9cm. wide with node; 3·8cm. long x 1·5cm. wide with possible nodal whorl; whorl segments measure 0·25cm. wide x 1·1 - 1·8cm long.
Specimen Number P.426.11
(Turn this photograph sideways to examine).

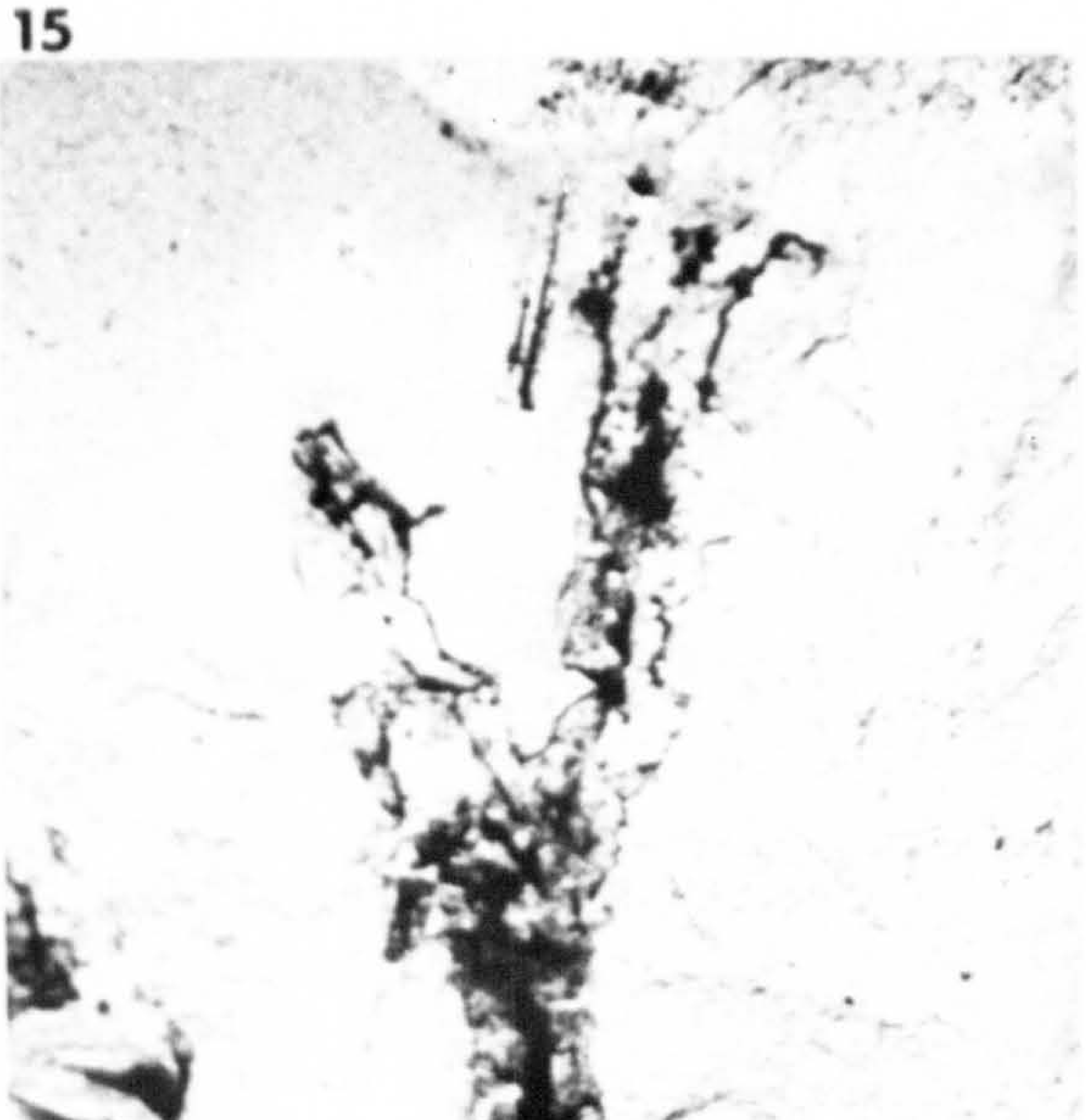
13

cm.

14

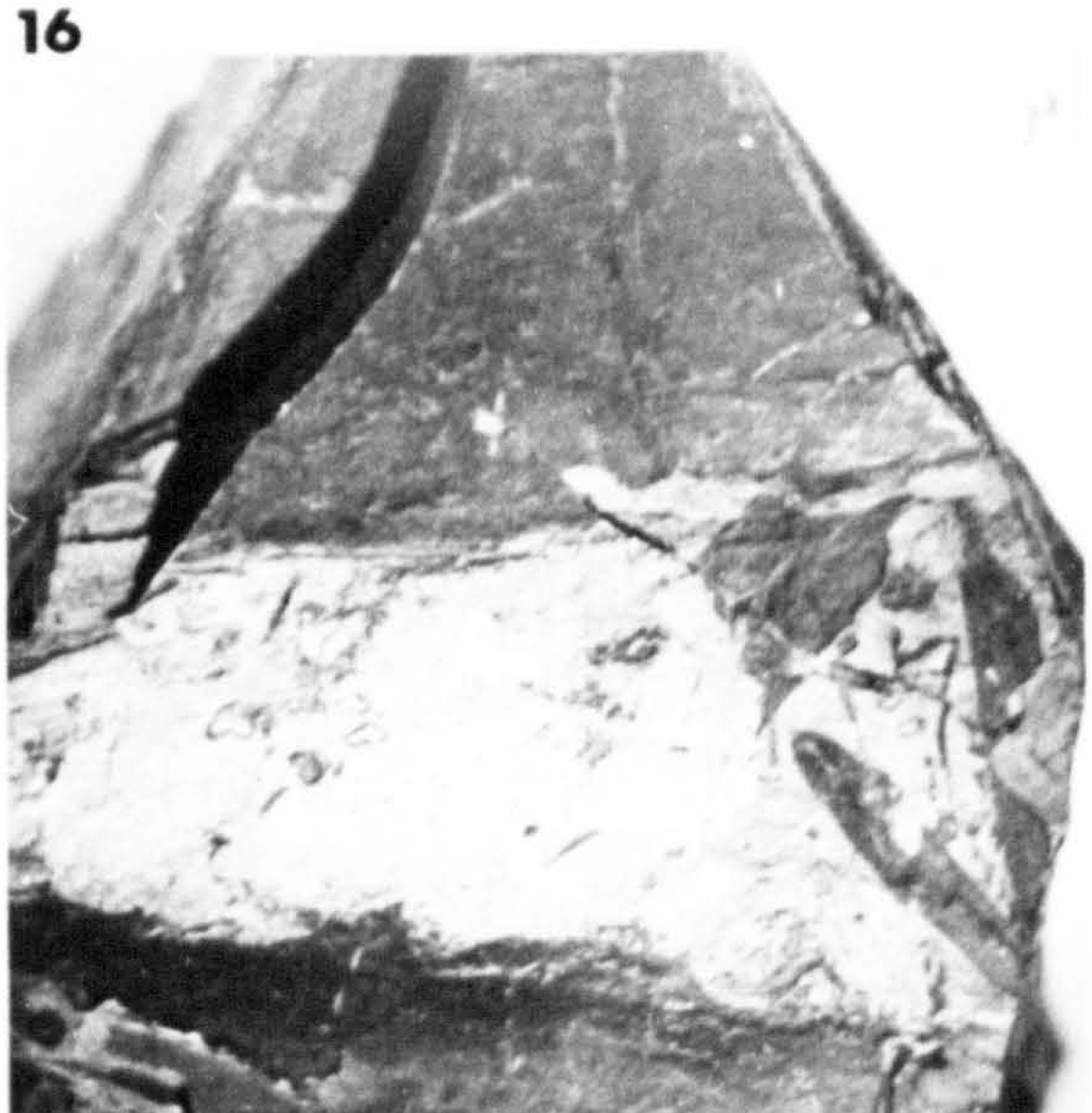
cm.

15



cm.

16



cm.

PLATE 5

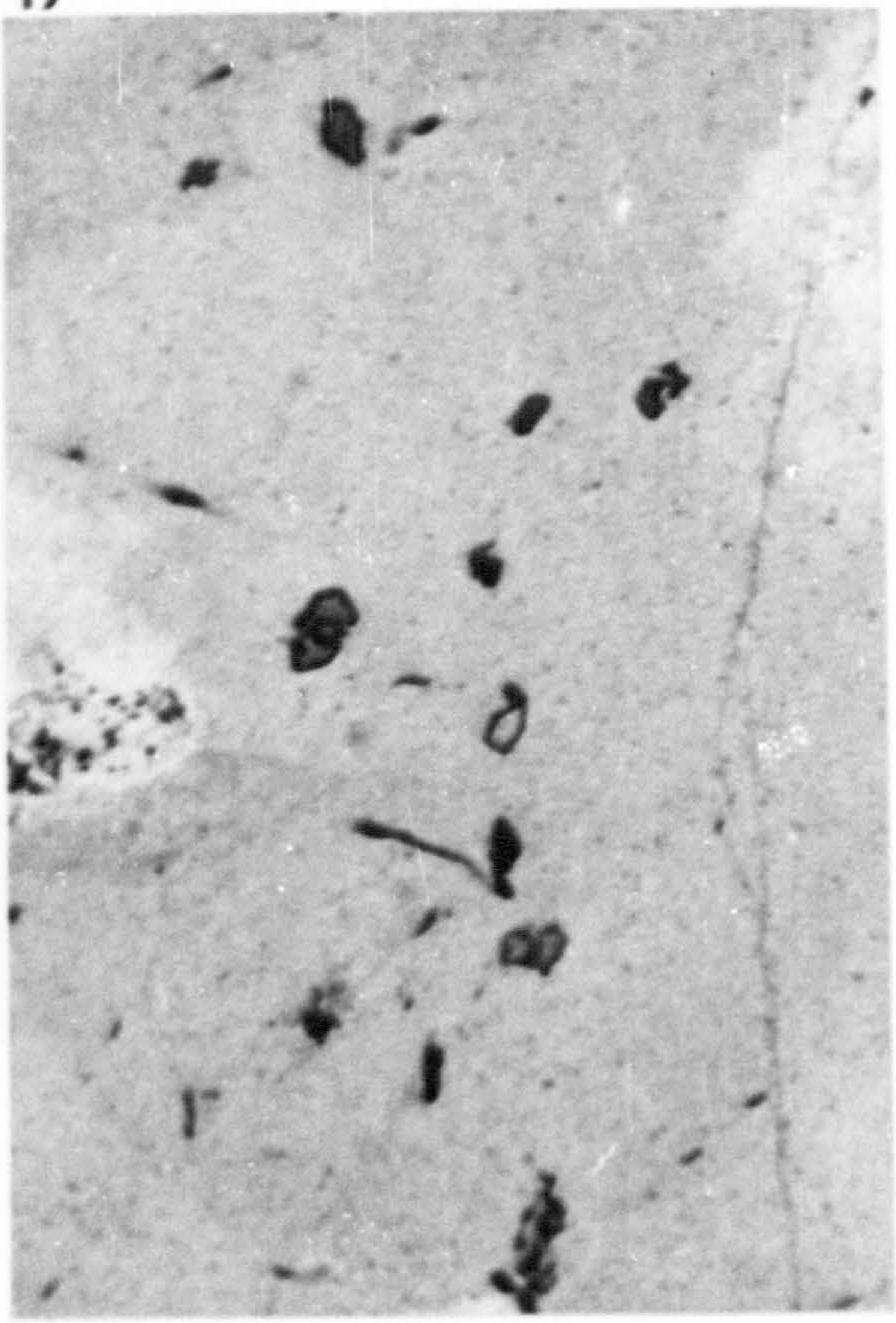
Plate 5·17 _Equisetites_ sp. Polished surface under xylol.
Axes measure 0·4 -1·6mm. wide.
Hobbs Specimen Number P.101.25

Plate 5·18 _Equisetites_ sp. 0·7mm. wide (maximum).
Slide Number 6.
Specimen Number P.224.25

Plate 5·19 _Equisetites_ sp. 0·75mm. wide (maximum).
Slide Number 6.
Specimen Number P.224.25

Plate 5.20 _Equisetites_ sp. Vertical fracture through bedding plane. Axes 1·5mm. wide (maximum).
Specimen Number P.426.13

17

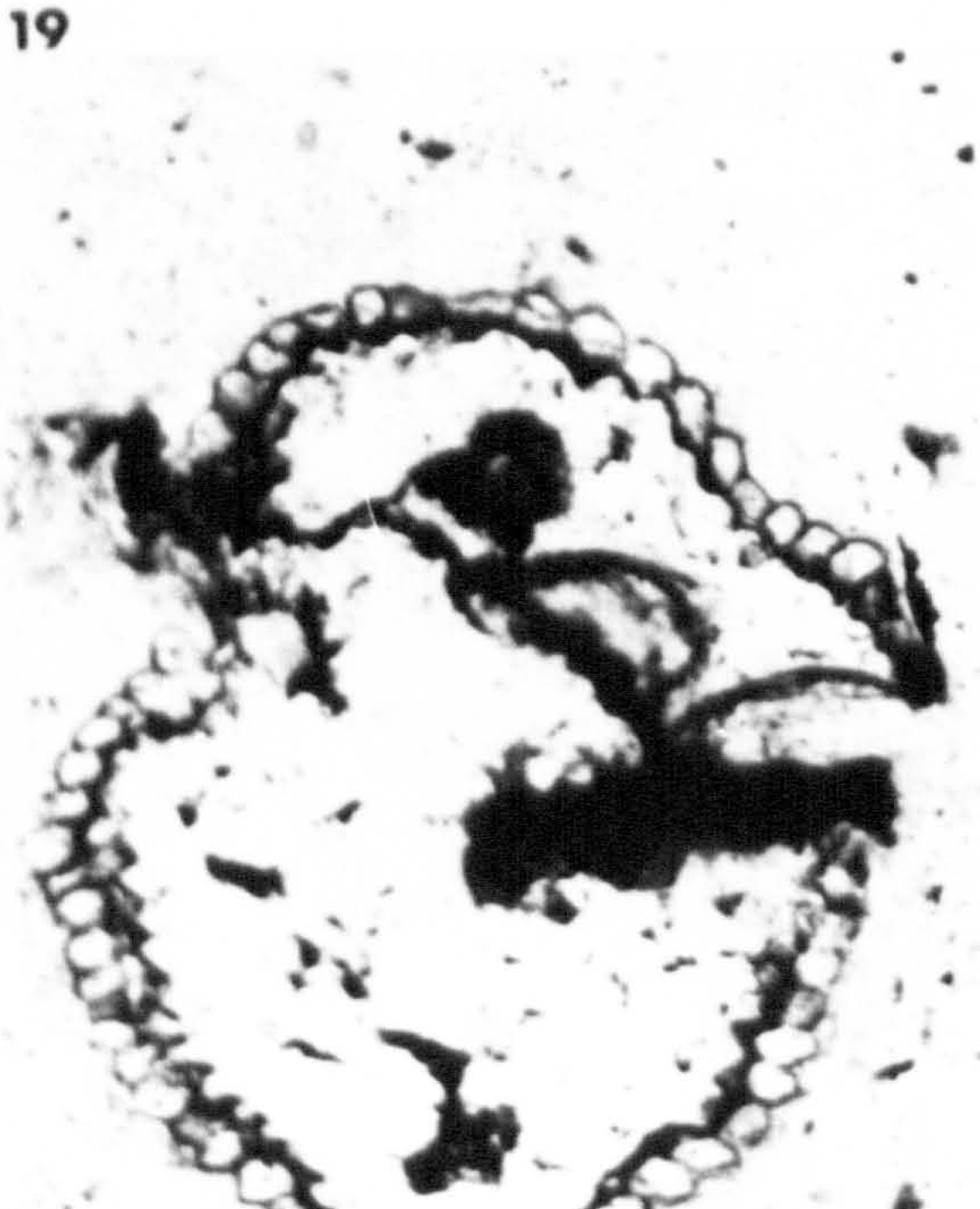


cm.

18

0·5mm.

19



0·5mm.

20

cm.

PLATE 6

Plate 6·21 cf. Asterotheca crassa. Fronds measure 2mm. wide and 1·1cm. - 2·25cm. long.

Specimen Number P.224.40

Plate 6·22 Transverse section of axis, possibly referable to Asterotheca crassa. 2·5mm. x 0·8mm. in size.

Slide Number 24.

Hobbs Specimen Number. P101.8

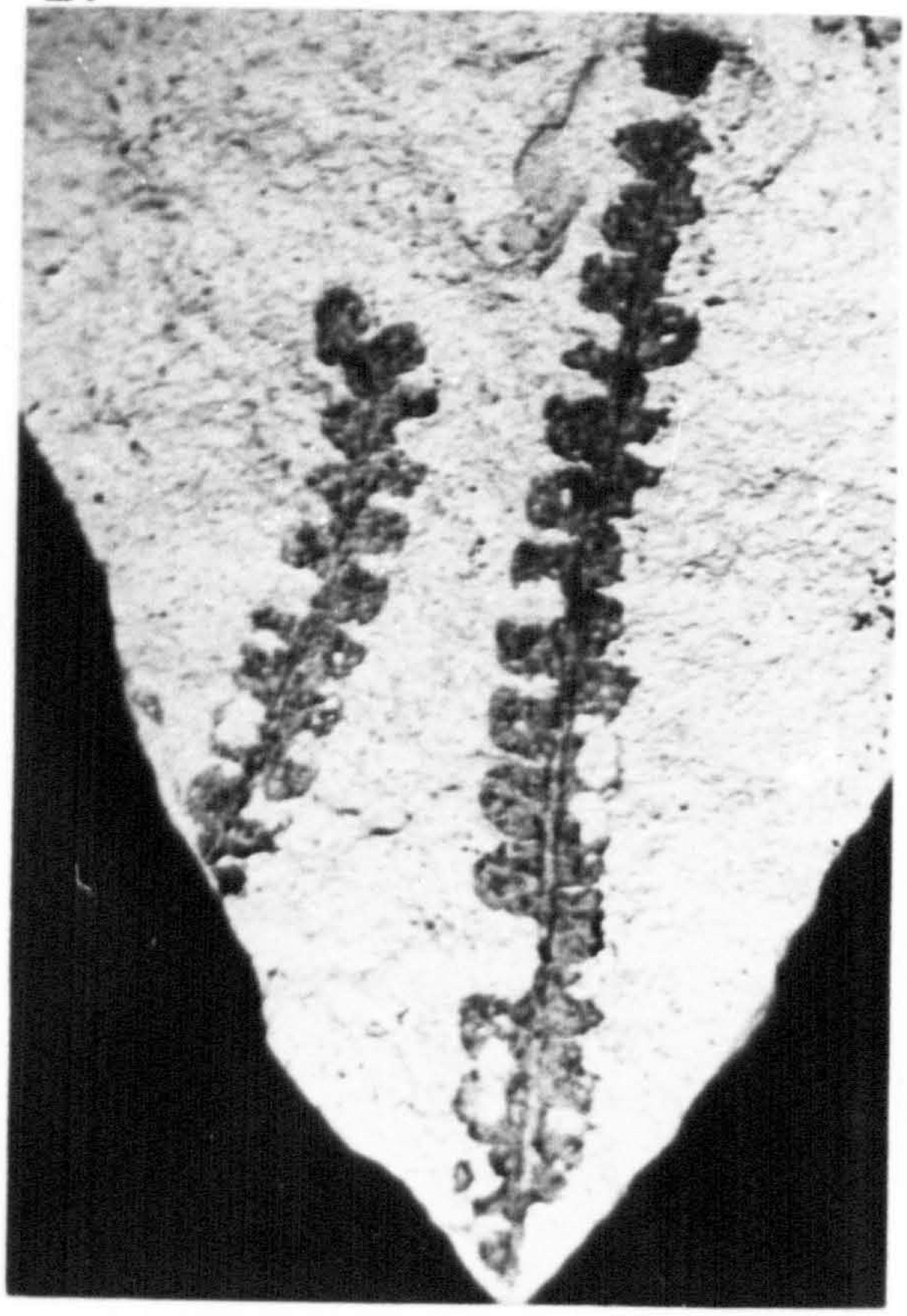
Plate 6·23 Dicroidium cf. lancifolium. 2·3cm. long x 1·25cm. wide.

Specimen Number P.224.38

Plate 6·24 Dicroidium cf. lancifolium. 2·4cm. long x 1·8cm. wide.

Specimen Number P.224.38

21



cm.

22

mm.

23

cm.

24

cm.

PLATE 7

Plate 7·25 Dicroidium (Xylopteris) cf. spinifolia. 6·5cm. long.
Specimen Number P.224.37

Plate 7·26 Dicroidium (Xylopteris) cf. spinifolia. 4·2cm. long.
Specimen Number P.224.26

Plate 7·27 Pterophyllum dentatum sp. nov. 3·0cm. long x 3·6cm. wide.
Specimen Number P.426.5

Plate 7·28 Macrozamia sp. from Australia, exhibiting toothed pinnae similar to those of Pterophyllum dentatum sp. nov.

25

cm.

26

cm.

27

cm.

28

cm.

PLATE 8

Plate 8·29 Pterophyllum dentatum sp. nov. Transverse section of rachis, 0·78mm. wide x 0·5mm. thick.

Slide Number 40.

Specimen Number P.426.6

Plate 8·30 Pterophyllum dentatum sp. nov. Vascular bundle and surrounding tissue. Magnification approximately X400.

Slide Number 40.

Specimen Number P.426.6

Plate 8·31 Pterophyllum dentatum sp. nov. Epidermis and cortical tissue. Magnification approximately X400.

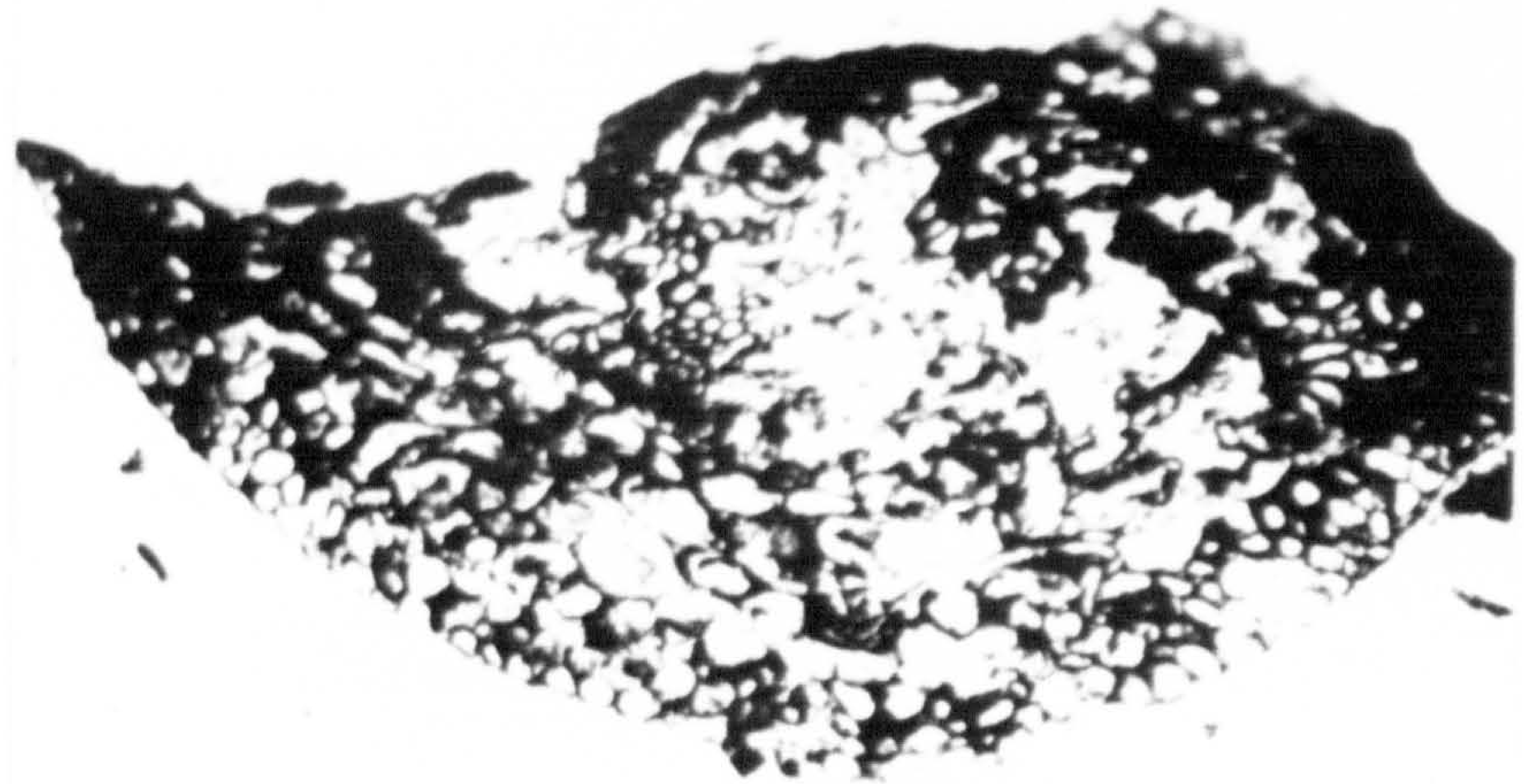
Slide Number 40.

Specimen Number P.426.6

Plate 8·32 Pterophyllum dentatum sp. nov. Tracheids seen in longitudinal section. Upper is annular/helical type, lower is reticulate type. Magnification approximately X650. Slide Number 45.

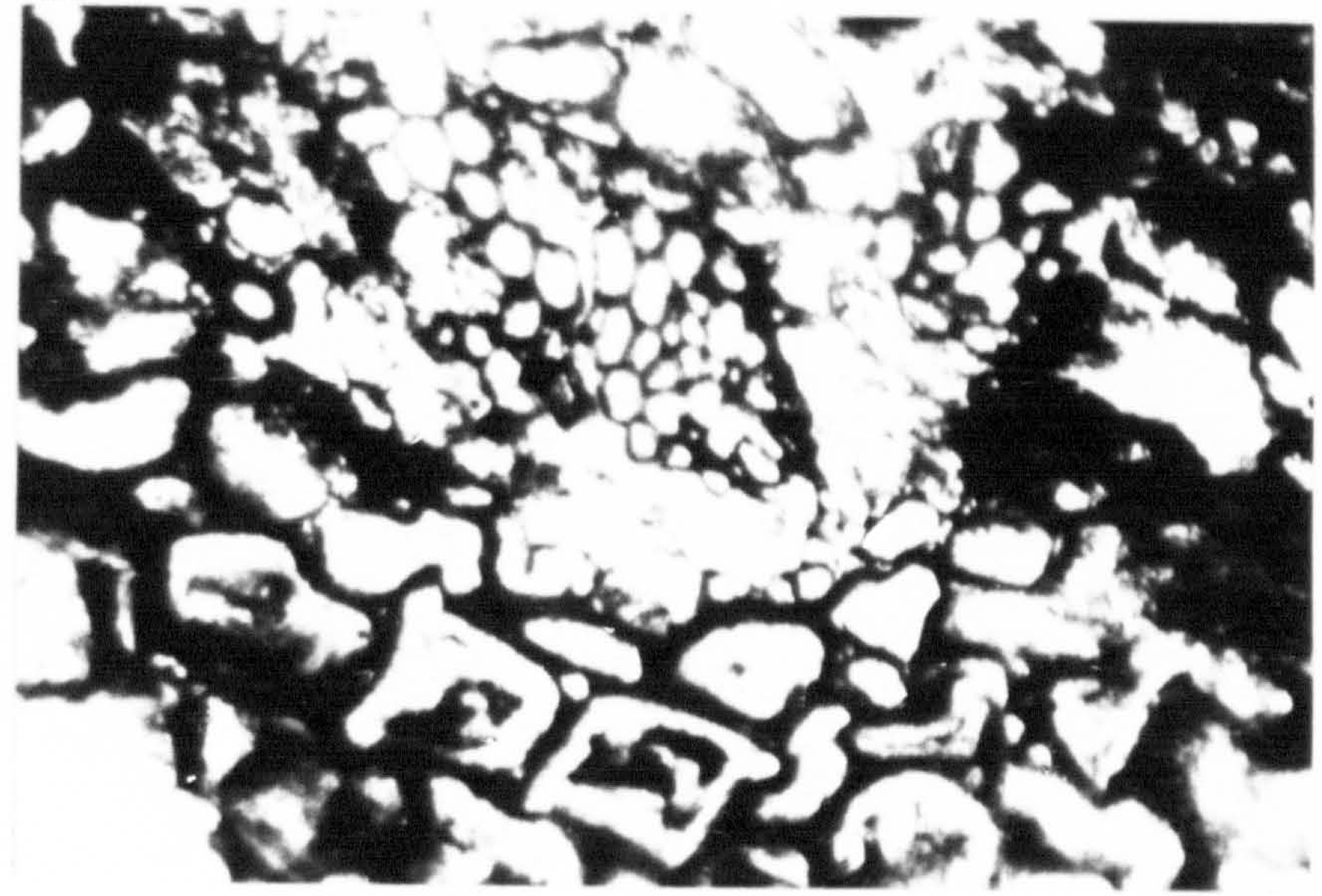
Specimen Number P.426.6

29



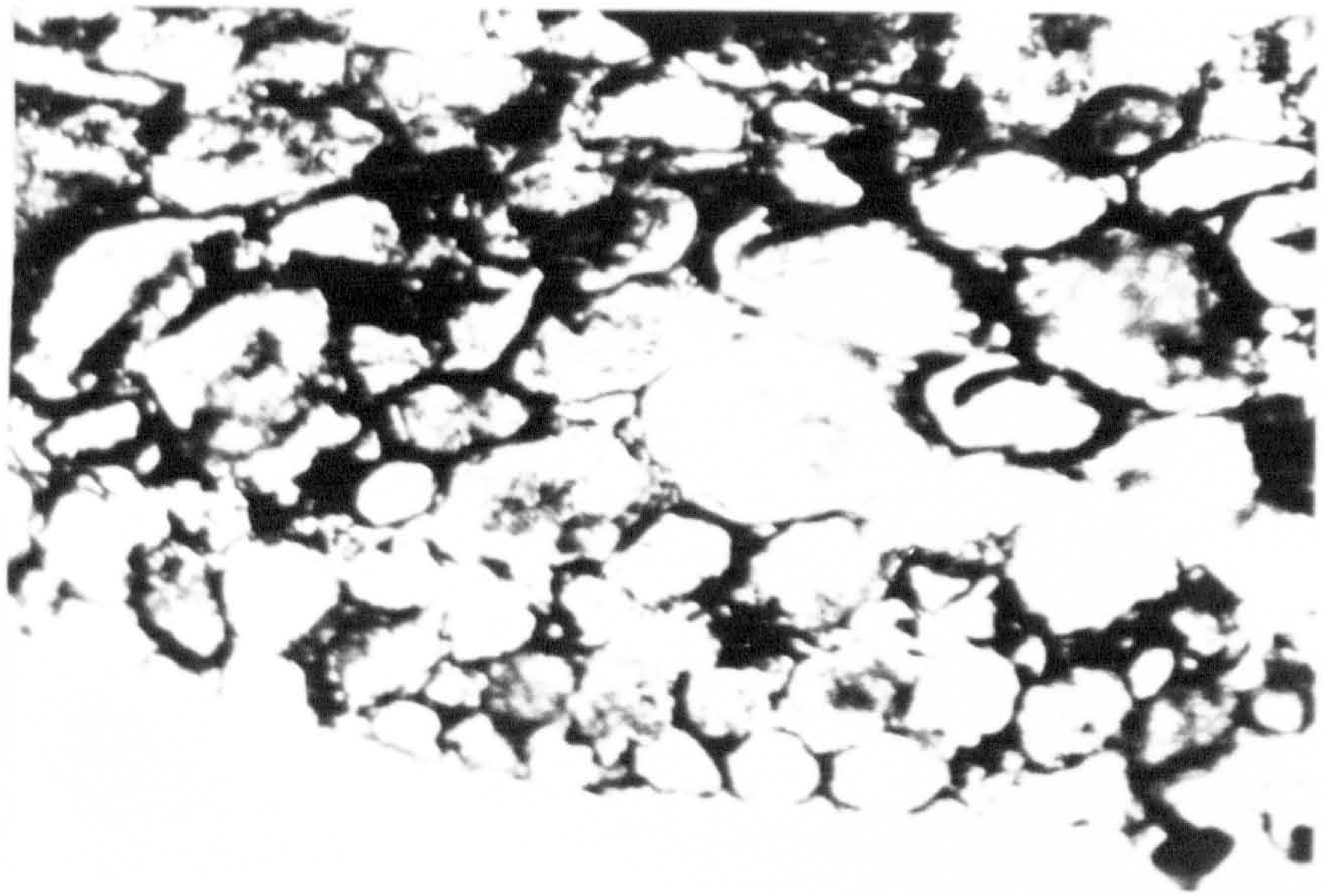
0·5 mm

30



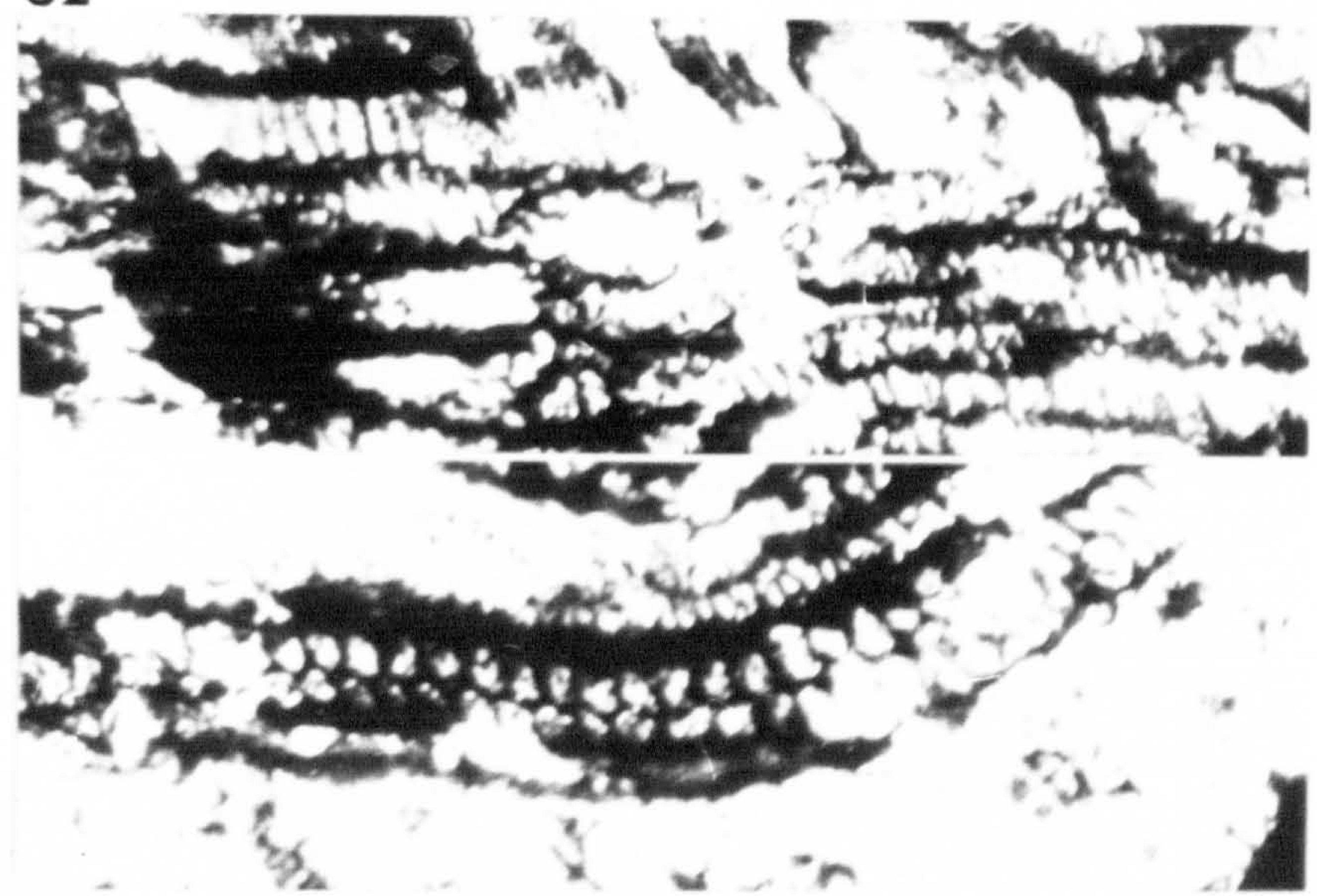
0·1 mm.

31



0·1 mm.

32



0·1 mm.

PLATE 9

Plate 9.33 Pagiophyllum sp. 2·65cm. long x 0·43cm. wide.

Specimen Number P.224.49

Plate 9.34 Pagiophyllum sp. 3·08cm. long x 0·47cm. wide.

Specimen Number P.224.42

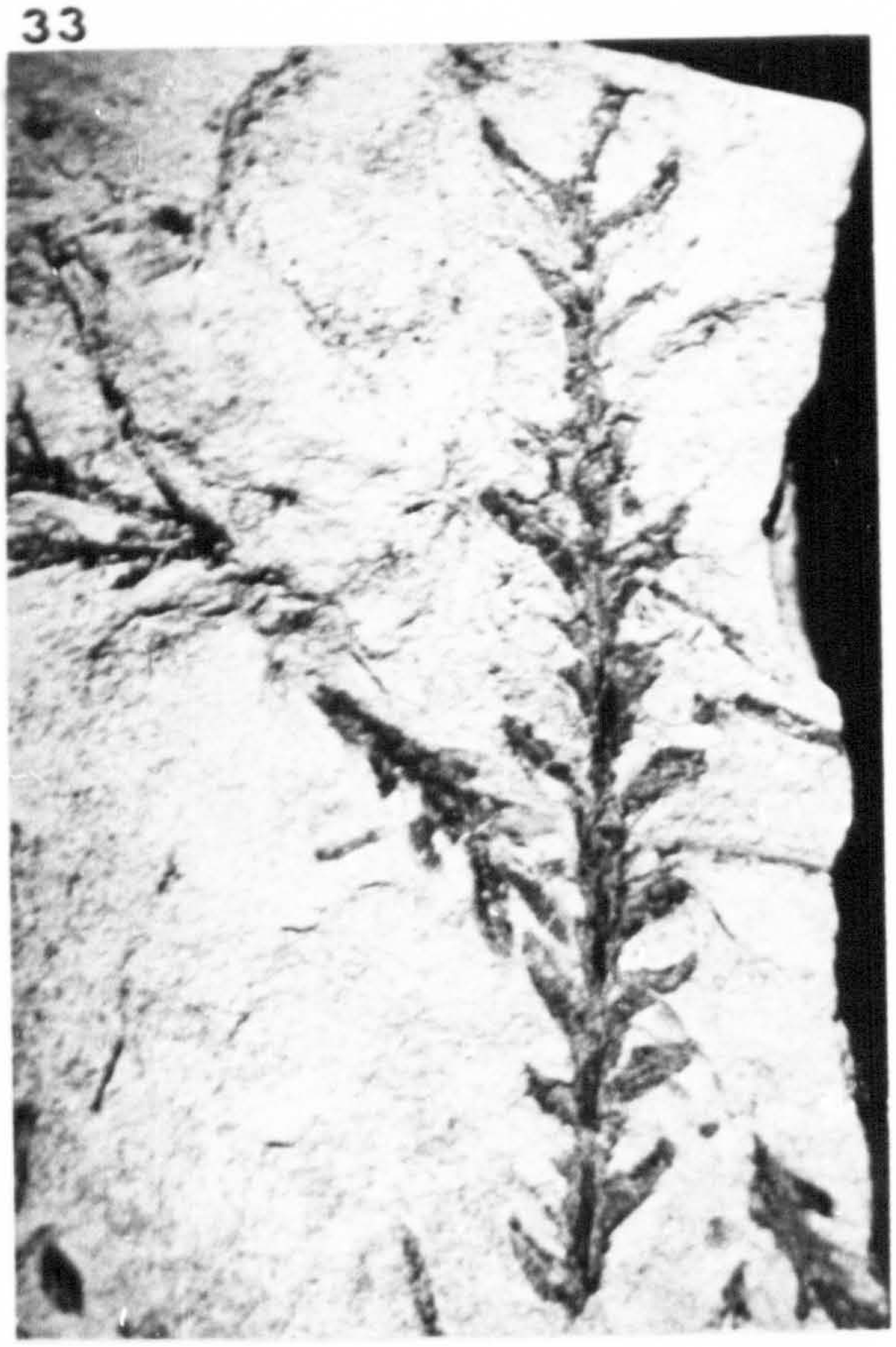
Plate 9.35 Pagiophyllum sp. 3·0cm. long x 0·25cm. wide.

Specimen Number P.224.34

Plate 9.36 Pagiophyllum sp. 2·3 cm. long x 0·5cm. wide.

Specimen Number P.224.49

33



cm.

34

cm.

35

cm.

36

cm.

PLATE 10

Plate 10·37 Pagiophyllum sp. 1·35cm. long x 6mm. wide.

Specimen Number P.224.31

Plate 10·38 Ginkgoites sp. 1·4cm. long x 1·3cm. wide.

Specimen Number P.224.27

Plate 10.39 Ginkgoites sp. 2·25cm. long x 1·70cm. wide.

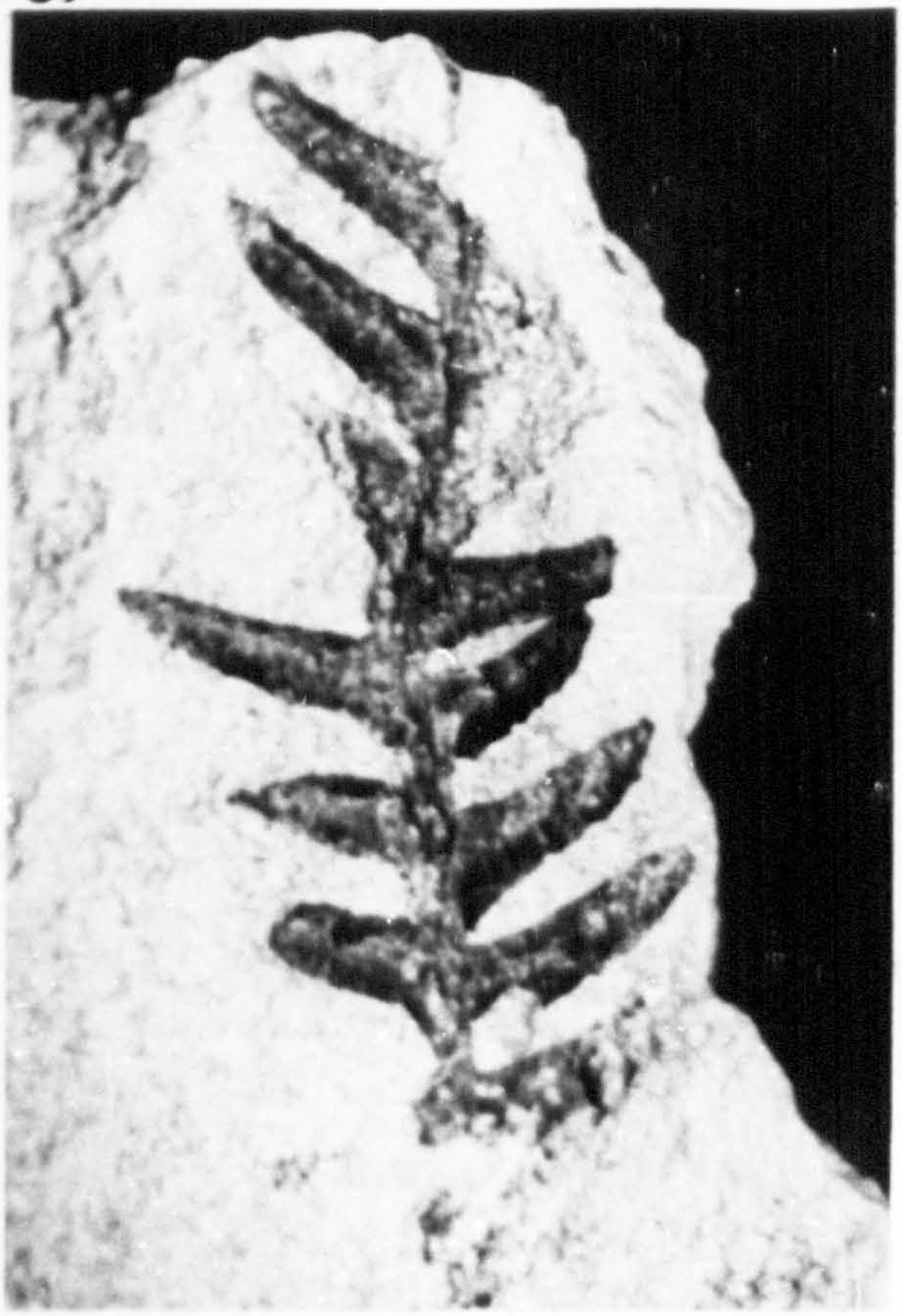
Hobbs Specimen Number P.101.25

Plate 10.40 Doratophyllum (Taeniopteris) tenison-woodsi

2·65cm. long x 0·5cm. wide.

Specimen Number P.224.36

37

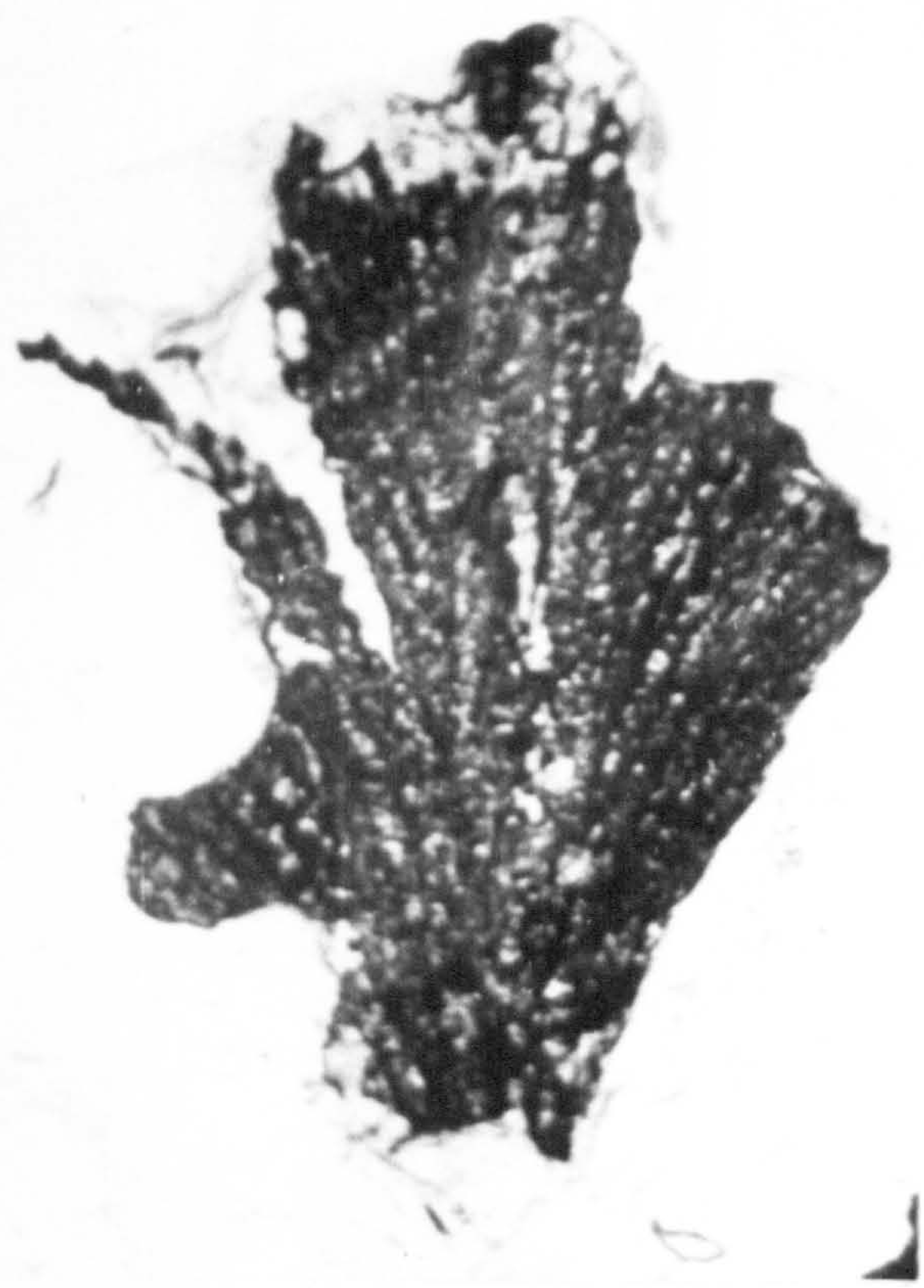


cm.

38

cm.

39



cm.

40

cm.

PLATE 11

Plate 11·41 _Hexagonocaulon_ _minutum_ gen. et sp. nov. Transverse section of axis. 3·15mm. wide (maximum).

Slide Number 18.

Specimen Number P.224.27

Plate 11·42 _Hexagonocaulon_ _minutum_ gen. et sp. nov. Radial - longitudinal section. 2·0mm. wide.

Slide Number 21.

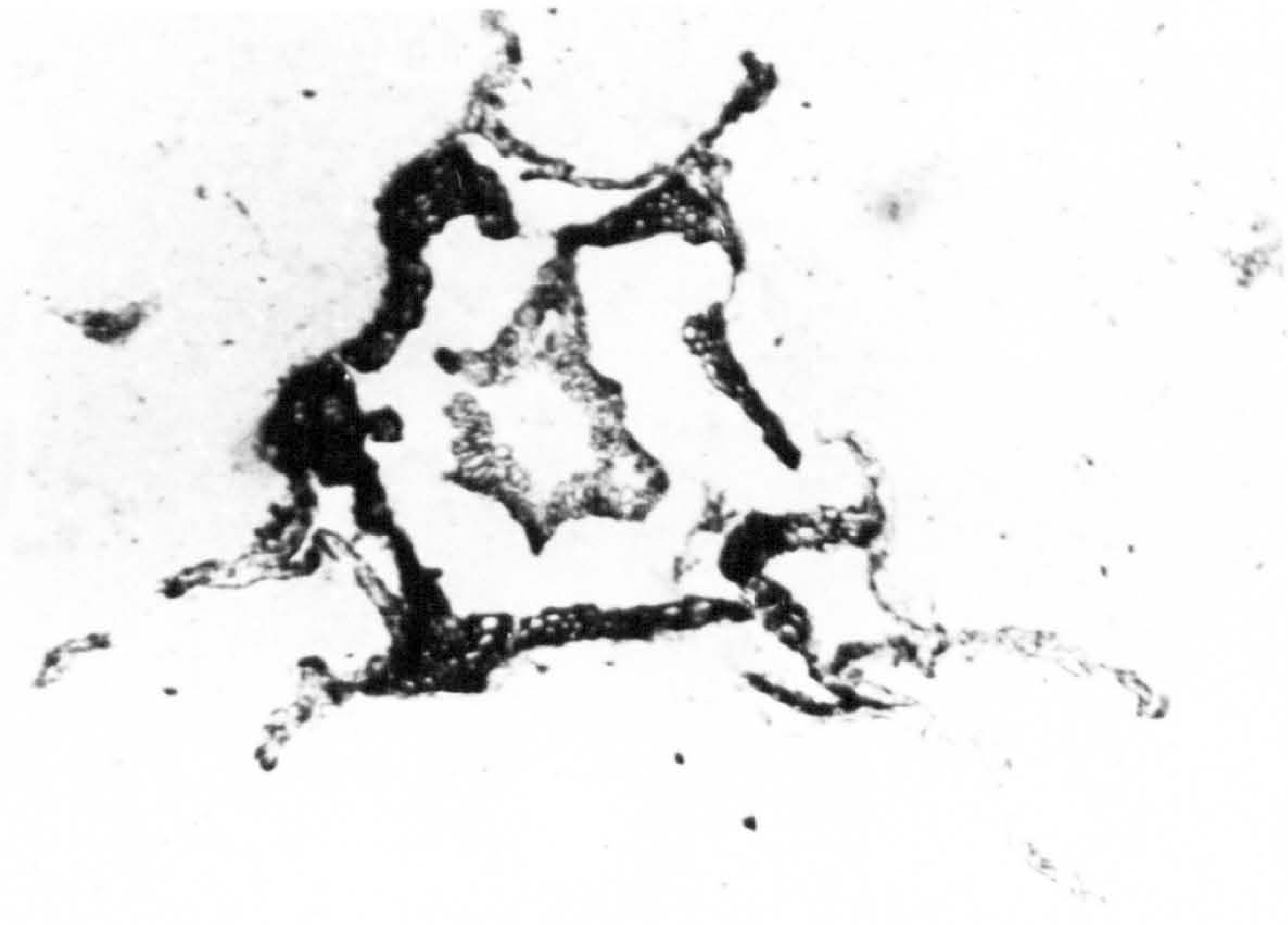
Specimen Number P.224.27

Plate 11·43 _Hexagonocaulon_ _minutum_ gen. et sp. nov. Stele ?. 0·8mm. wide (maximum).

Slide Number 18.

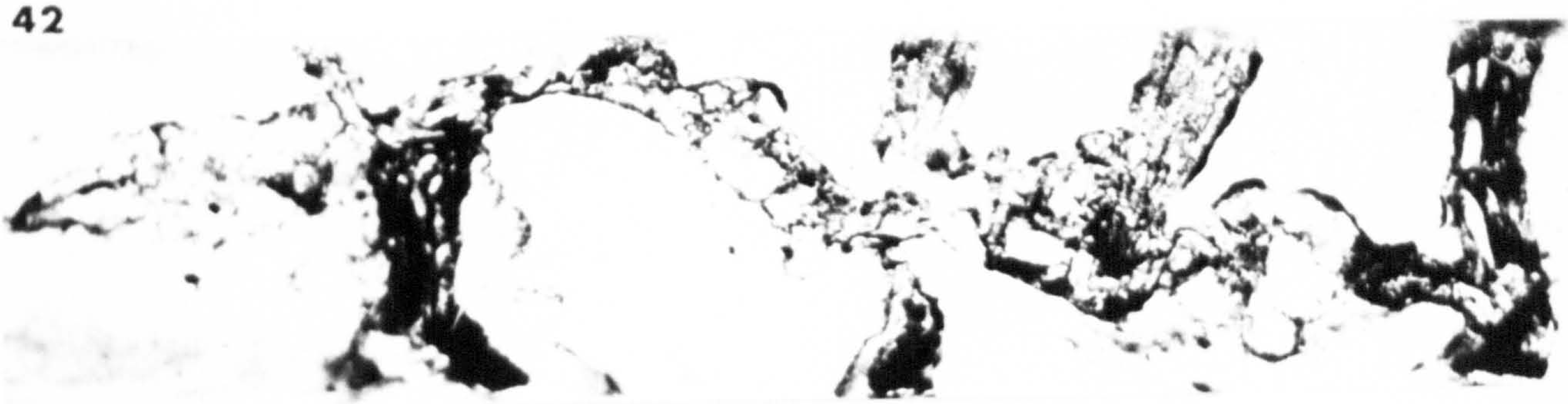
Specimen Number P.224.27

41



mm.

42



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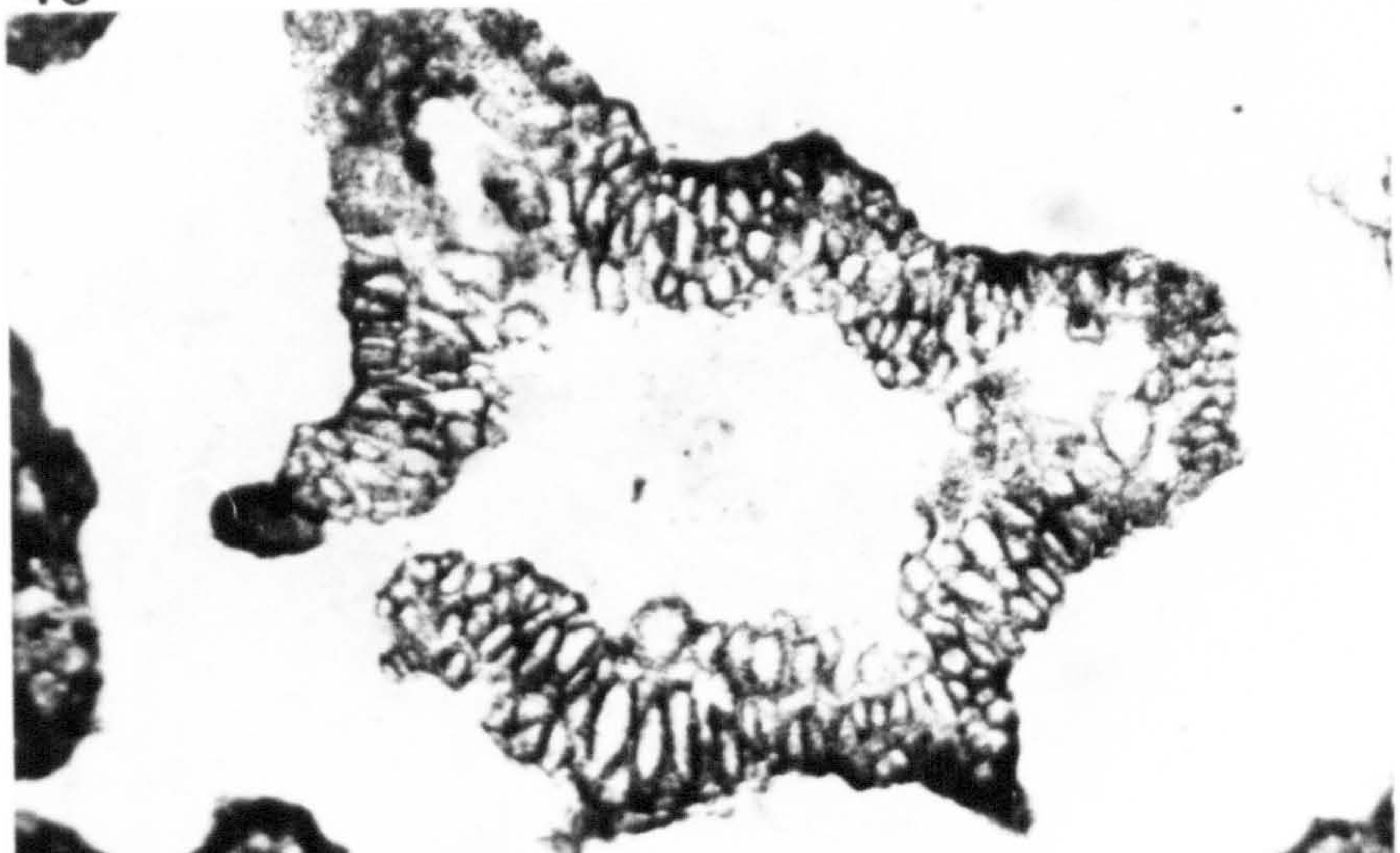
43



0·5 mm.

PLATE 12

Plate 12·44 Hexagonocaulon minutum gen. et sp. nov. Transverse section. 3·28mm. wide (maximum).

Slide Number 17.

Specimen Number P.224.27

Plate 12·45 Hexagonocaulon minutum gen. et sp. nov. Transverse section. 1·80mm. wide (maximum).

Slide Number 24.

Specimen Number P.224.29

Plate 12·46 Hexagonocaulon minutum gen. et sp. nov. Transverse section. 3·75mm. wide (maximum).

Slide Number 10.

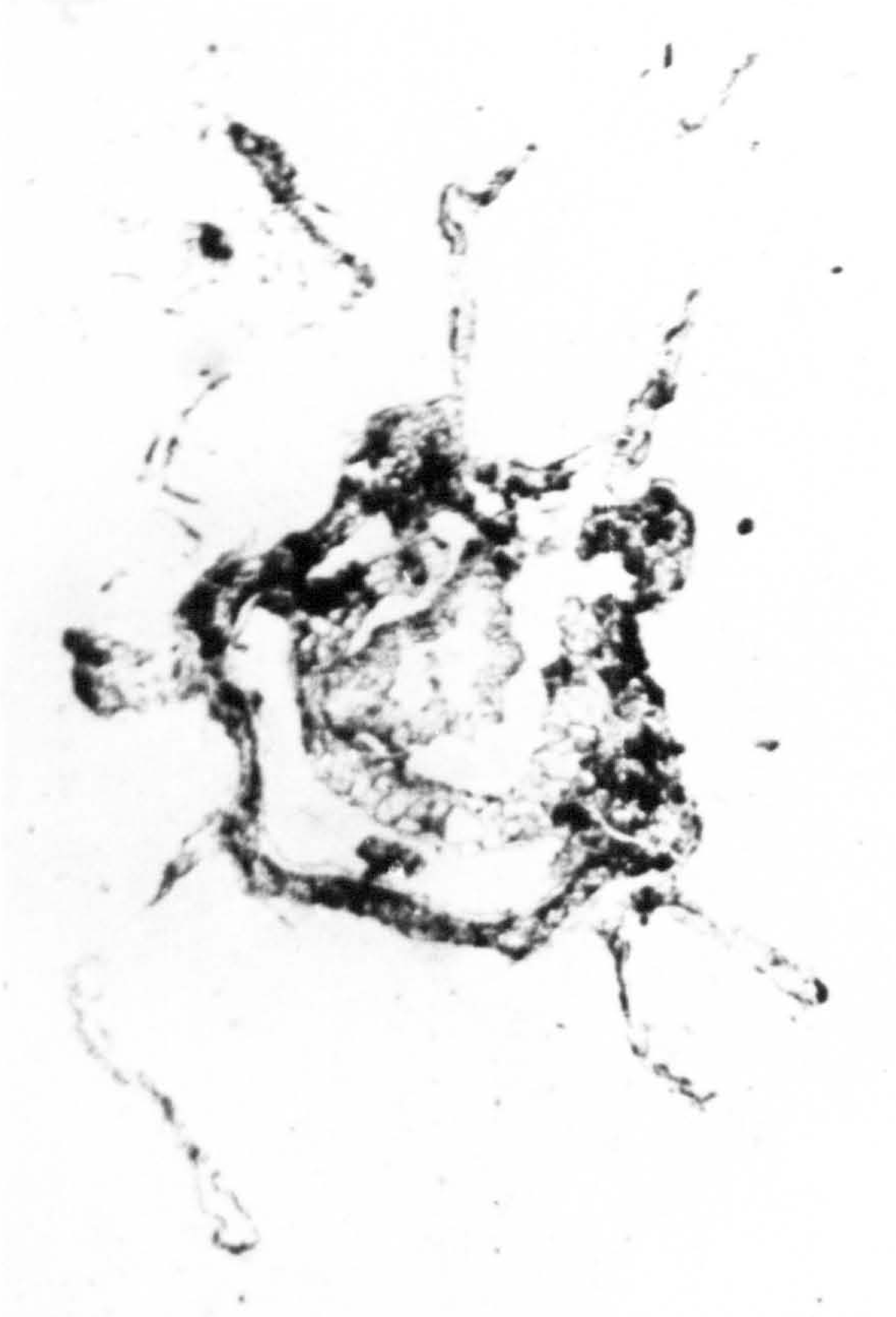
Specimen Number P.224.21

Plate 12·47 Hexagonocaulon minutum gen. et sp. nov. Transverse section. 2·7mm. wide (maximum).

Slide Number 18.

Specimen Number P.224. 27

44



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45

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46

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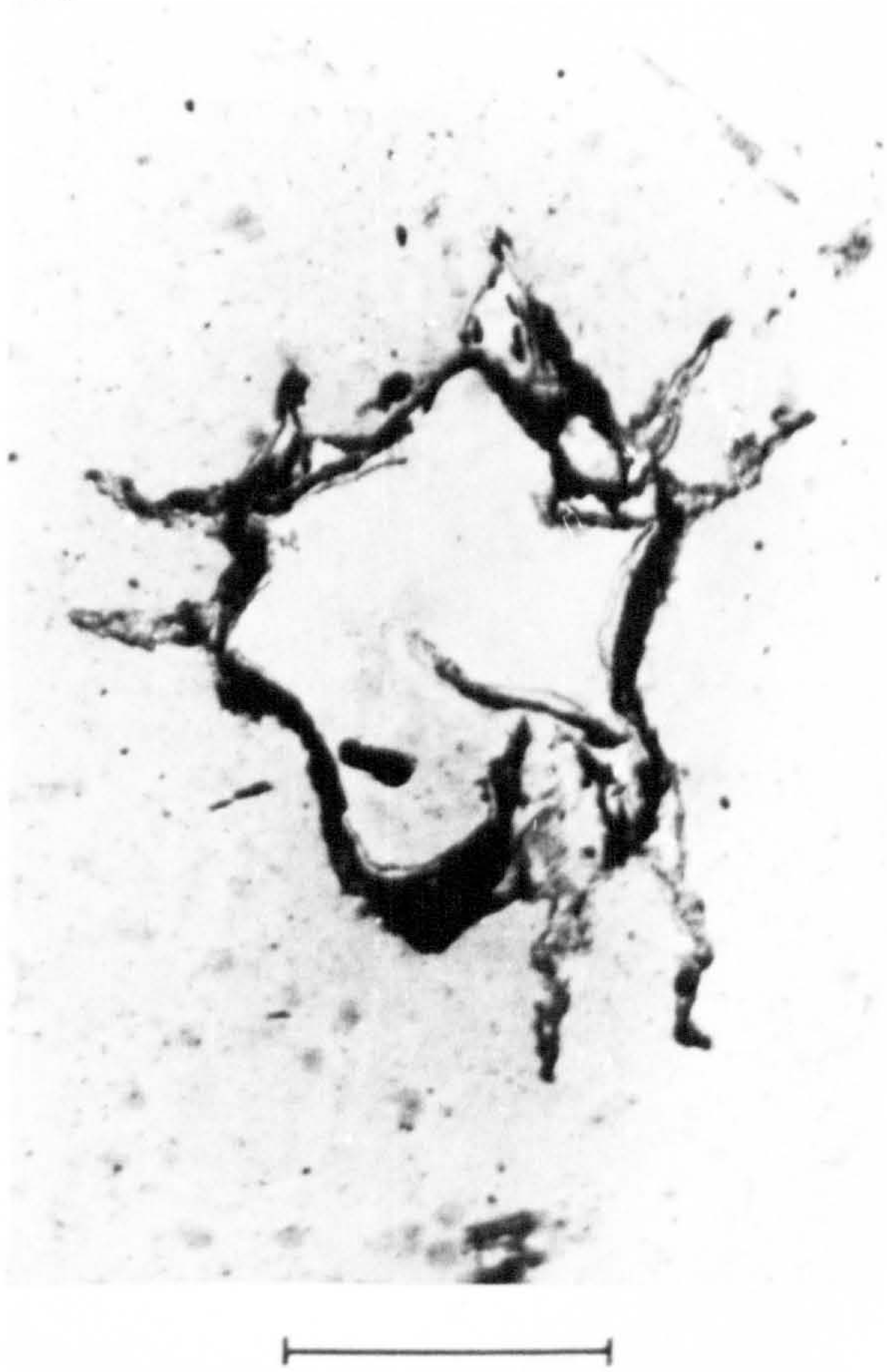
47



mm.

PLATE 13

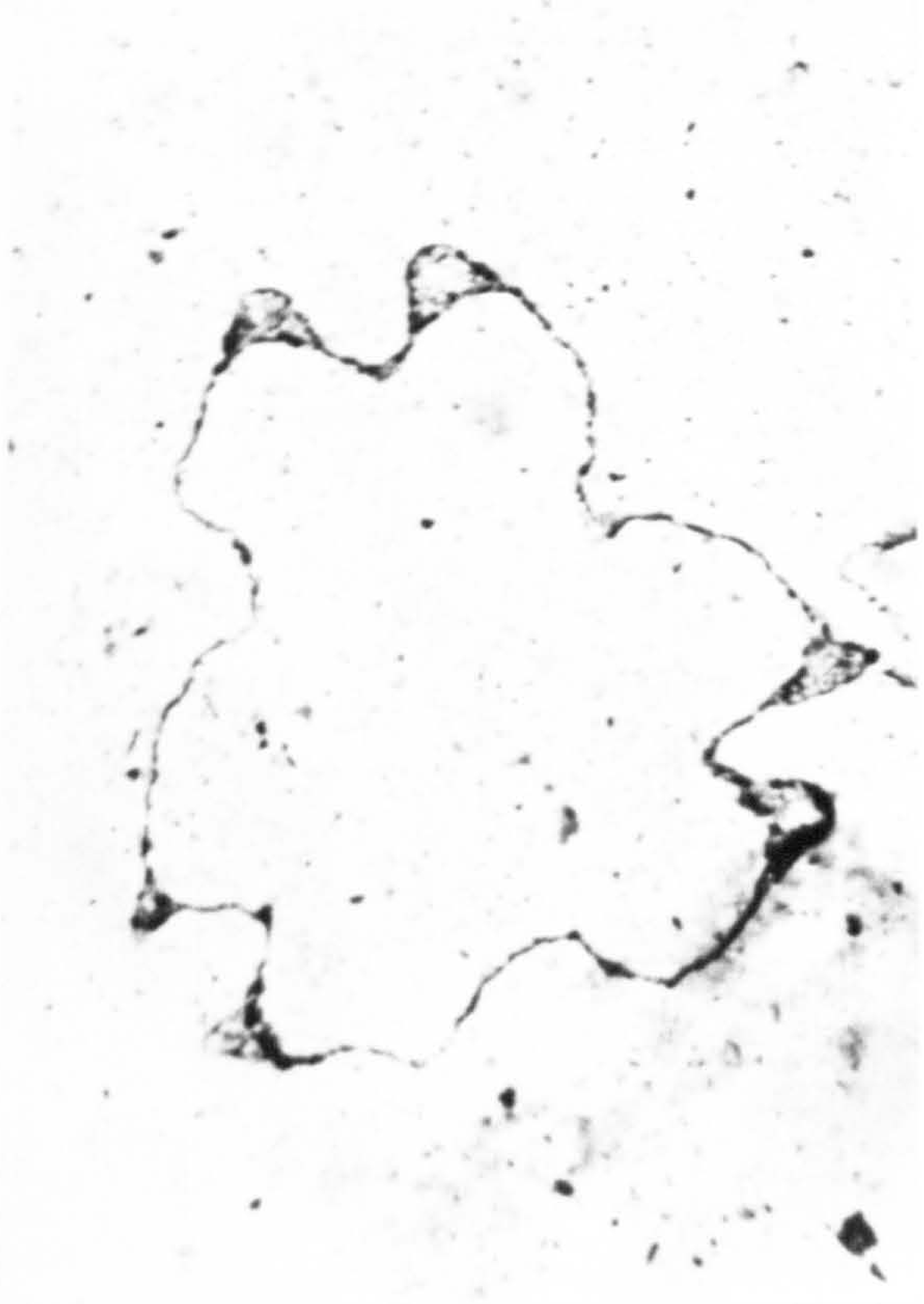
Plate 13·48 Hexagonocaulon minutum gen. et sp. nov. Transverse section. 1·70mm. wide (maximum).
Slide Number 14.
Specimen Number P.224.27

Plate 13·49 Hexagonocaulon minutum gen. et sp. nov. Transverse section. 1·7mm. wide (maximum).
Slide Number 14.
Specimen Number P.224.27

Plate 13·50 Axis (indeterminate). 1·3mm. wide (maximum).
Slide Number 22.
Specimen Number P.224.22

Plate 13·51 Axis (possibly large Asterotheca crassa type). 2·2mm. wide (maximum).
Slide Number 36.
Specimen Number P.224.32

48



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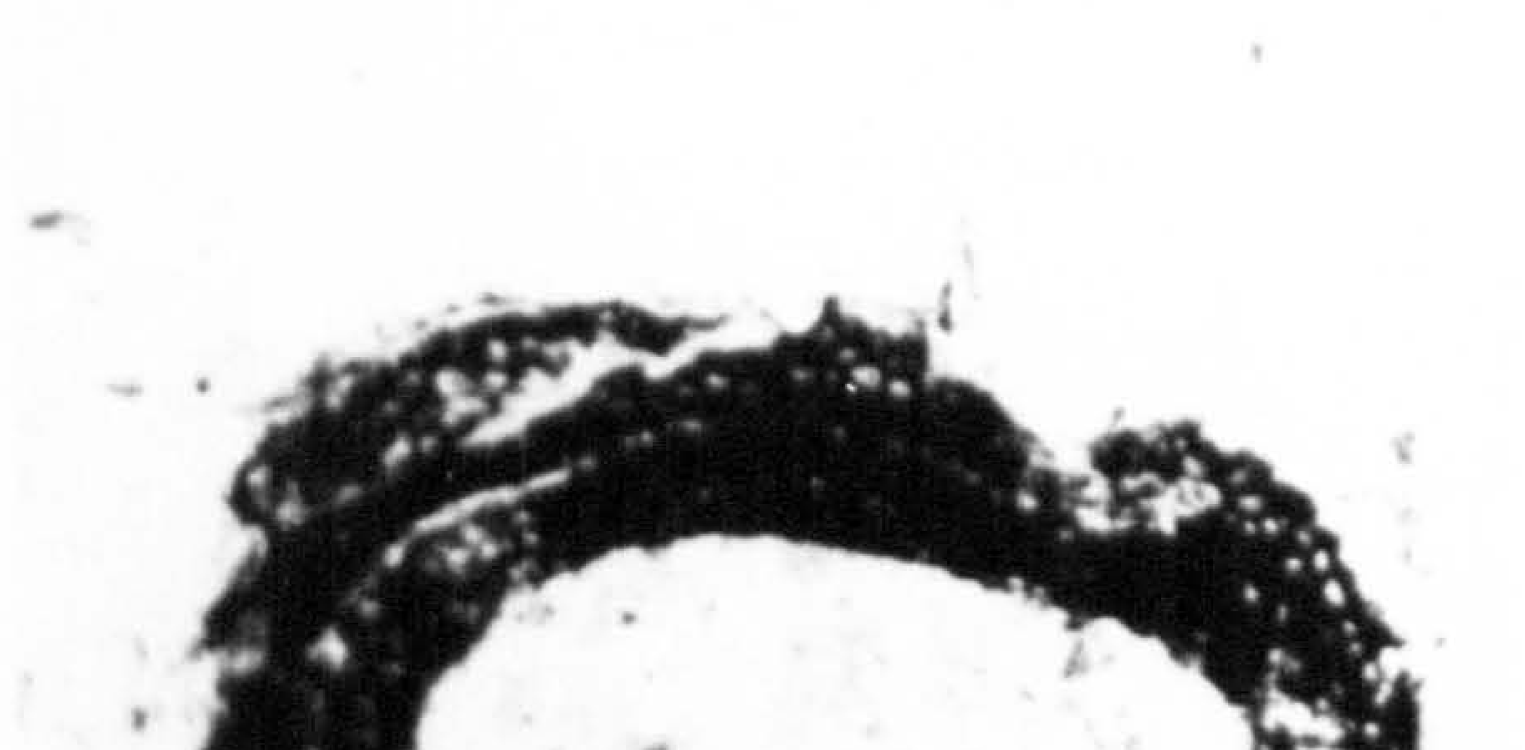
50



mm.

51

mm.

PLATE 14

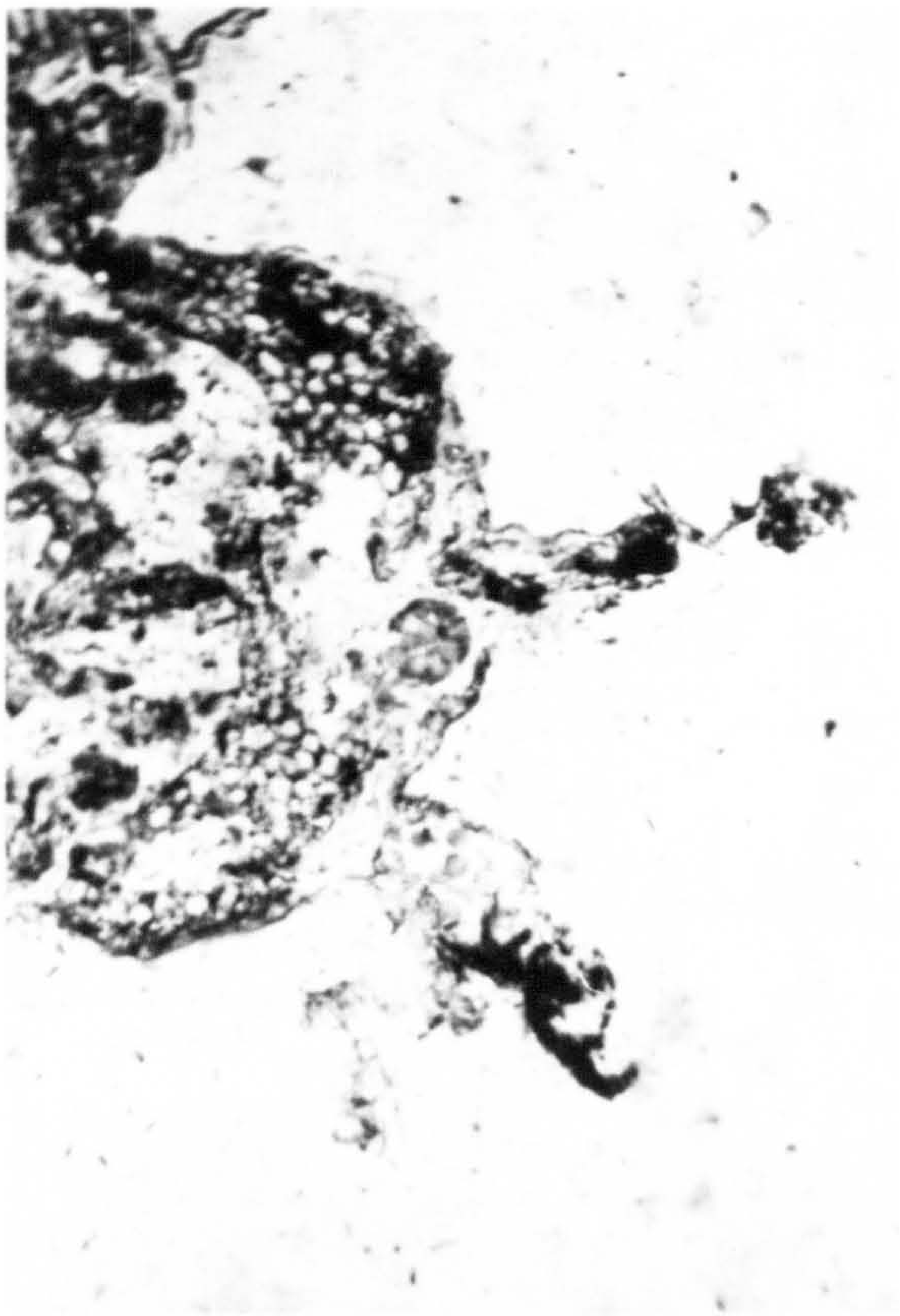
Plate 14·52 Spore cluster found within axis of Hexagonocaulon minutum gen. et sp. nov. Cluster diameter measures 180μm. (maximum) in diameter.
Slide Number 11.
Specimen Number P.224.21

Plate 14·53 Details of spore cluster seen in Plate 14·52.
Slide Number 11.
Specimen Number P.224.21

Plate 14·54 Single spores and filaments observed in the matrix surrounding the axis. Spores measure up to 27μm. wide, filaments measure 10μm. thick x 286μm. long.
Slide Number 11.
Specimen Number P.224.21

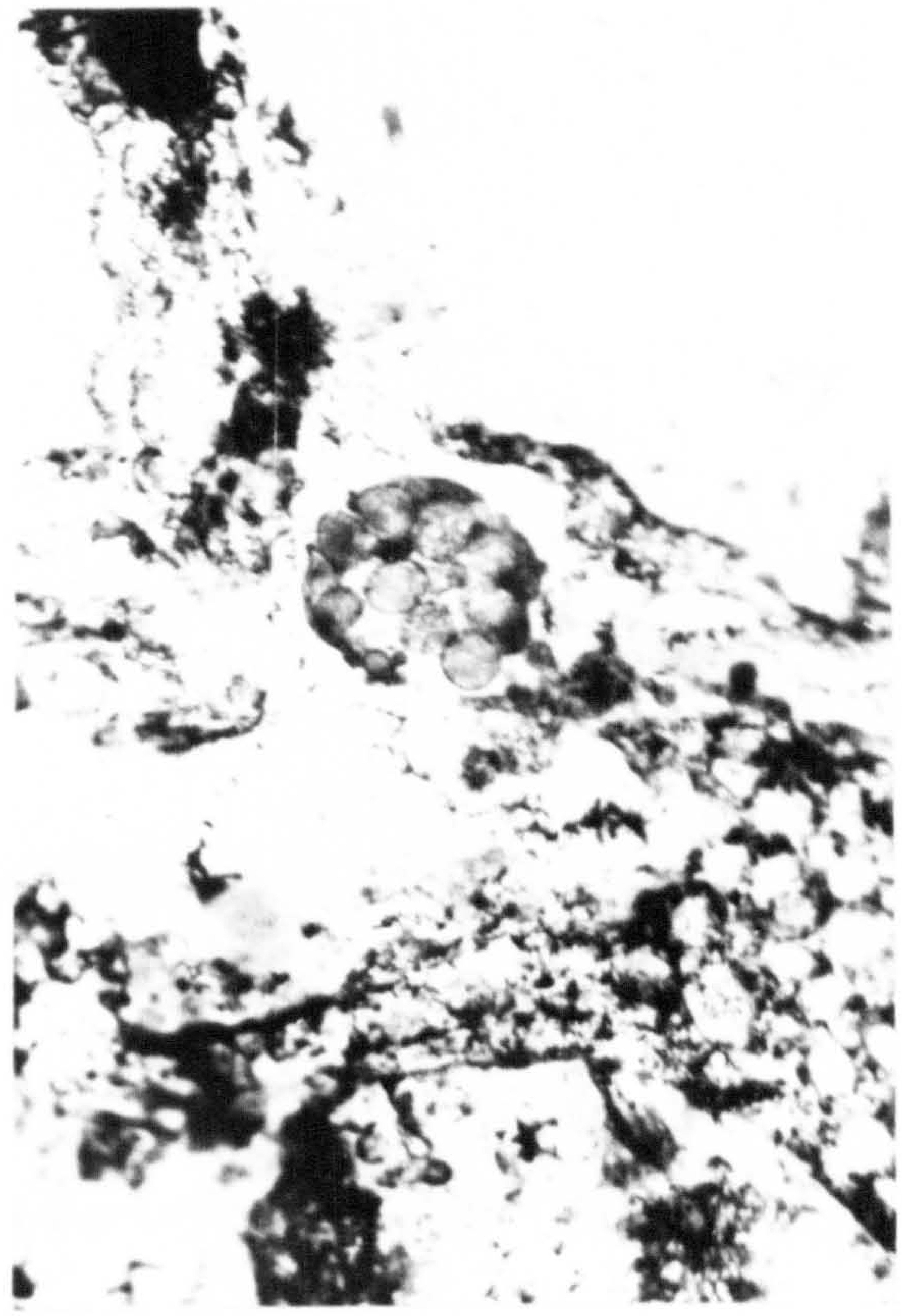
Plate 14·55 Spore group found within axis of Hexagonocaulon minutum gen. et sp. nov. Spores measure up to 42·5μm. in diameter.
Slide Number 11.
Specimen Number P.224.21

52



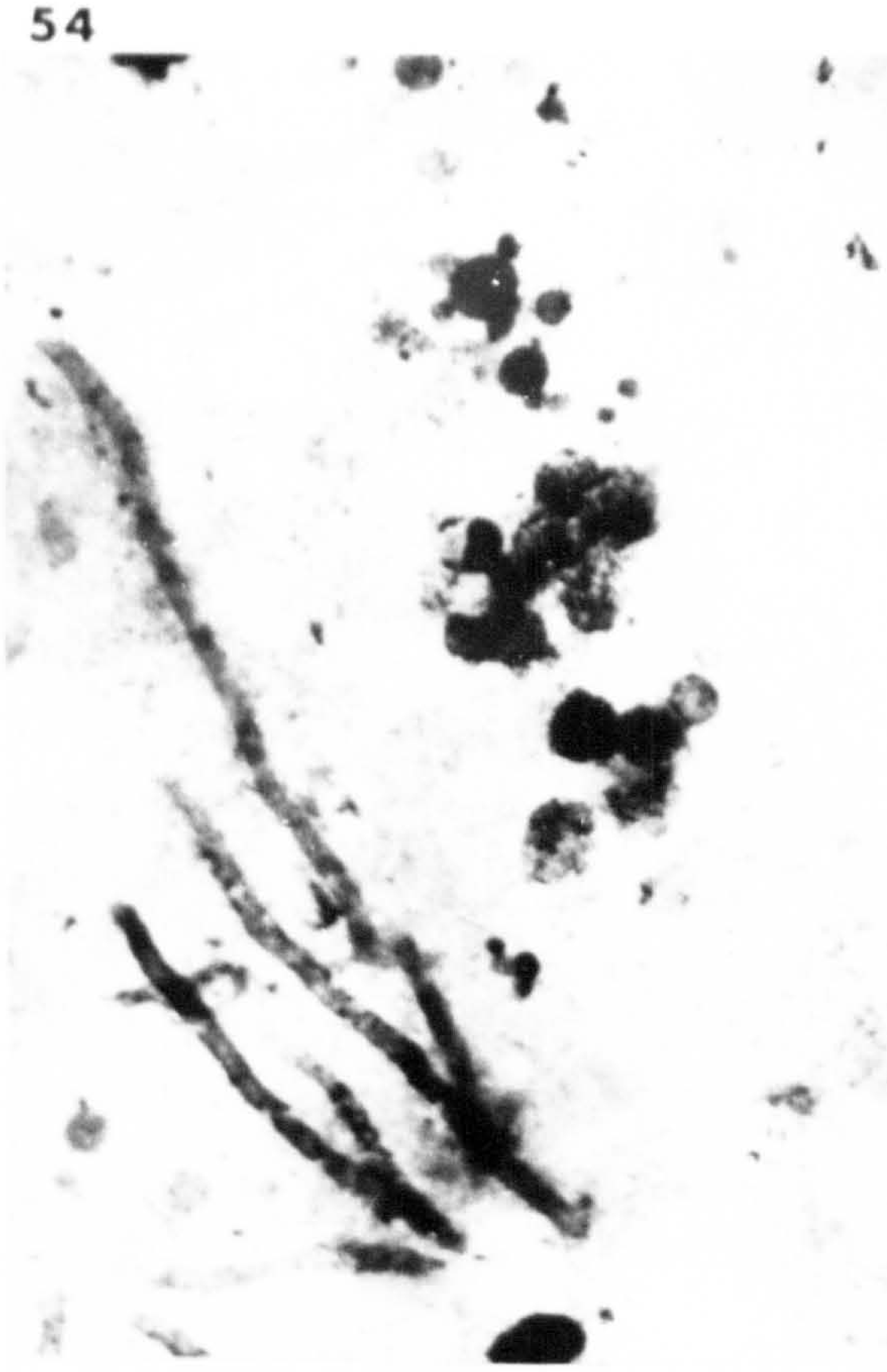
mm.

53



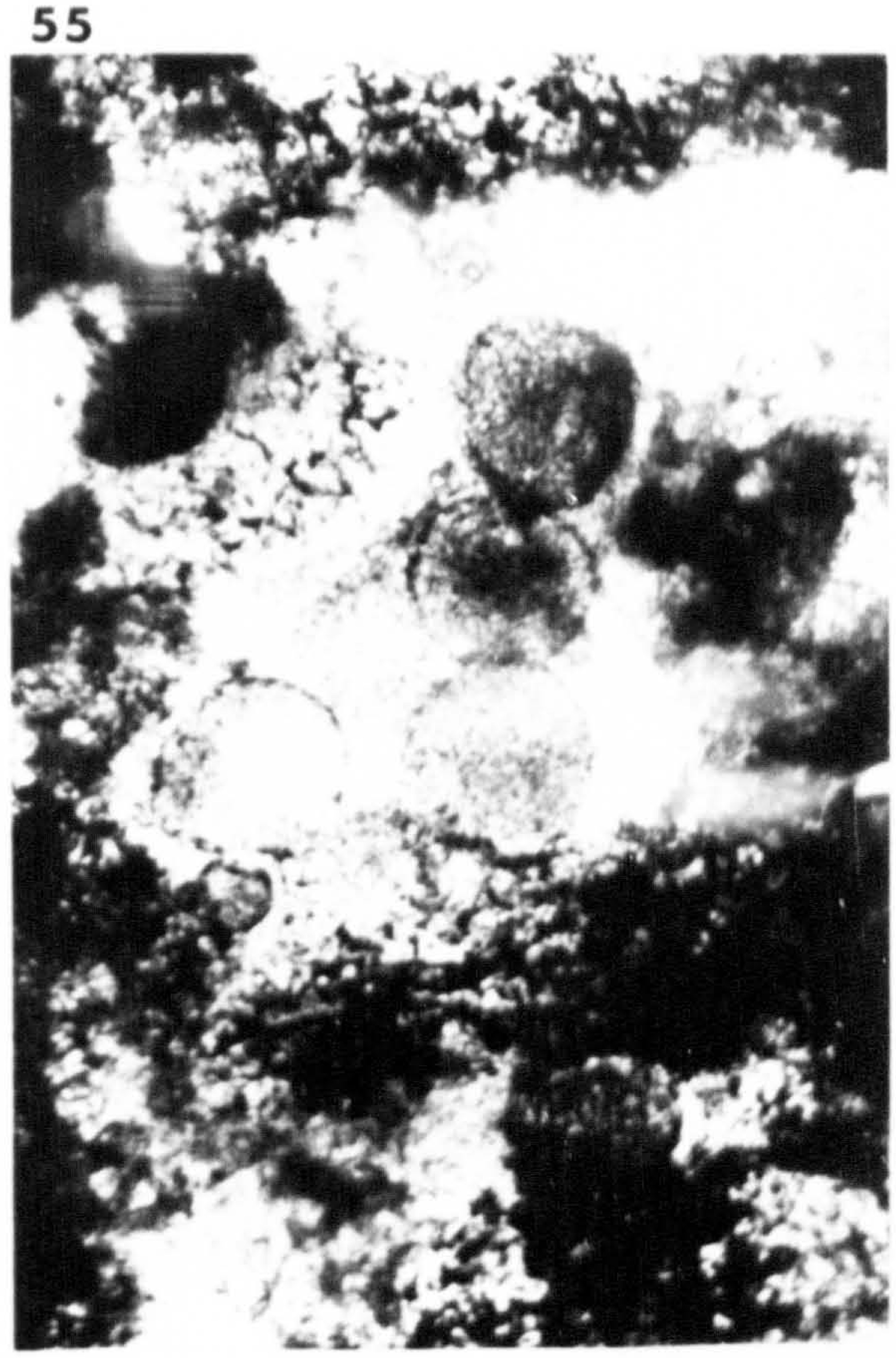
0·5mm.

54



0·1mm.

55



0·1mm.

# CHAPTER THREE

# A TERTIARY FLORA FROM KING GEORGE ISLAND

# CHAPTER 3

## SUMMARY

Eleven specimens of fossil wood, collected from Keller Peninsula, King George Island in the South Shetlands, Antarctica have been examined in detail using both optical and scanning electron microscope techniques.

It is suggested that at least four species are represented and three of these are reasonably well preserved.

Accurate stratigraphic determination is difficult, although the woods are thought to be of Tertiary (possibly early Tertiary) age.

## INTRODUCTION

Gothan (1908) described Dadoxylon pseudoparenchymatosum and Dadoxylon sp., plus two other wood taxa from Seymour Island near the Antarctic Peninsula.

This was later followed by Seward (1914) who described Antarcticoxylon priestleyi from supposed Triassic deposits in Priestley glacier.

In 1928 Edwards recorded Dadoxylon sp. after re-examining material collected on Ferrar's Antarctic Expedition of 1901 - 1904.

Gordon (1930) has also recorded Dadoxylon (Araucarioxylon) sp. from the Bay of Isles in the Islands of South Georgia.

Material collected on the famous Trans - Antarctic Expedition of 1955 - 1958 included two specimens of wood from Allan Nunatak (Victoria Land), these being Dadoxylon allani and Taeniopitys scottii (Kräusel, 1962).

Schopf (1962, 1973) has recorded Antarcticoxylon sp. from both Permian and Triassic deposits, further evidence which casts doubt on the age determination of the material from Priestley glacier.

A description of the largest collecton of fossil woods from Antarctica was made by Maheshwari (1972) and includes ten woods of Palaeozoic age from various sites, three of these being new species.

Dadoxylon sp. was recorded by Plumstead (1975) from poorly preserved specimens found in material of Permian or Carboniferous age at Milorg-fjella in Dronning Maud Land.

Apart from South Georgia, fossil wood has also been recorded from the Falkland Islands, where Dadoxylon cf. angustrum and Dadoxylon lafoniense were recorded by Halle (1912) and Dadoxylon bakeri was later described by Seward and Walton (1923), all from Permian or Carboniferous deposits.

## MATERIAL

King George Island is the largest member of the South Shetlands Group and is situated between latitude 61°50′ and 62°15′S and longitude 59°45′ and 61°15′W. The island measures approximately 78 kilometres (49 miles) long and up to 29 kilometres (18 miles) wide and lies between Nelson Island to the West and Bridgeman Island to the East (refer to Text Figure 43).

The material was collected by C. M. Barton during geological surveying for the British Antarctic Survey from Keller Peninsula in the central bay of the island.

Keller Peninsula consists of a north by north-westerly dipping sequence of andesitic lavas and pyroclastic rocks. From early days in the geologic exploration of King George Island, its volcanic rocks were divided stratigraphically into Jurassic and late Cretaceous to early Tertiary strata (refer to Table 14) and because of their highly altered state, the rocks of Keller Peninsula were assigned to the Jurassic or Upper Jurassic (Hawkes, 1961 and Barton, 1965).

The Jurassic succession is 250 metres (800 feet) thick, the lower half composed entirely of andesitic lavas, the upper half of coarse agglomerates and tuffs and containing occasional wood fragments (Adie, 1964). The woods are carbonized, silicified and calcified and although no associated leaves have been found it is possible that they are comparable to the woods from the Upper Jurassic rhyolites of Cape Disappointment (Barton, 1965). These rocks pre-date the Andean Intrusive Suite (late Cretaceous-early Tertiary) and exhibit strong petrological affinities with the Upper Jurassic volcanic rocks of the nearby Antarctic Peninsula.

Rocks previously mapped as Jurassic on Fides Peninsula (Grikurov and

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Polyakov, 1968) and in the Marian Cove and Admiralen (Davies, in press 1 & 2) have been critically re-examined and the criterion that Jurassic volcanic rocks can be recognized by their state of alteration has been strongly questioned. In the three cited instances there is evidence that the altered rocks are early Tertiary in age and the presence of any Jurassic rocks at all in King George Island should be viewed with caution (Thomson - pers. comm.).

Two fossil sites yielding wood were found on Keller Peninsula although all have similar numbers (refer to Text Figure 44).

1. Two un-numbered blocks, designated G.536.A and G.536.B (site locality unknown).

2. G.536.2, G.536.3, G.536.4, G.536.6, G.536.7 and G.536.8 were collected from moraines scattered over the surface.

3. G.536.9, G.536.13 and G.536.14 were collected from 'in situ' agglomerate exposed in a rock ridge on the south side of Noble Glacier, approximately one kilometre north of the old Falkland Island Dependency Survey base area.

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## POSITION OF THE GENUS DADOXYLON

Most Palaeozoic fossil wood was assigned arbitrarily to the form genus *Dadoxylon* Endlicher 1847 and in most cases little attention was paid to any primary tissues which may have been preserved. *Dadoxylon* is thought to represent the wood of the Cordaitales, a member of the Coniferopsida found only in the fossil flora.

Problems arose when wood, seemingly identical to *Dadoxylon* was discovered in Mesozoic and younger strata.

The Cordaitales became extinct by the end of the Permian period (Sporne, 1974) and so the generic name *Araucarioxylon* Kraus 1870 was applied to these woods, mainly on the grounds that it could not belong to the Cordaitales (and hence *Dadoxylon*) and so must be assigned to another genus. The fact that the Type species of *Araucarioxylon*, *A. carbonaceum* was described from the Carboniferous of England was ignored.

The use of age as a criterion for taxonomic distinction is very unsatisfactory and although supported by Arber (1905) and White (1908), it was strongly criticised by Seward (1919) and later authors.

The problems inherent in identifying wood as either *Dadoxylon* or *Araucarioxylon* from deposits of uncertain age and their subsequent potential use as stratigraphic indicators are obvious.

Walton (1925) first proposed the genus *Trigonomyelon* for *Dadoxylon pedroi* Zeiller on the character of its preserved pith. Since then, many workers (Kräusel, 1928, 1956, 1962; Kräusel and Dolianti, 1958; Surange and Maithy, 1962, 1963 and Maheshwari, 1966) have assigned wood species with preserved primary tissues to taxa other than *Dadoxylon*.

This has to some extent greatly reduced the number of species of *Dadoxylon* although problems of assigning specimens which possess only secondary wood still remain.

Greguss (page 17-18, 1967) suggests that Dadoxylon should be restricted to woods which have uni - triseriate (rarely 4 - 10) rays, irrespective of whether there are araucarian, spiral or annular thickenings in the tracheids.

Recent Araucaria and Agathis species with araucarian pitting always have uniseriate (exceptionally partly biseriate) rays. This fact has been taken up by Maheshwari (1972) who suggests that woods with uniseriate and rarely partly biseriate rays should not be assigned to Dadoxylon but to Araucarioxylon.

Lepekhina and Yatsenko - Khmelevsky (1966) and Lepekhina (1972) retain Araucarioxylon, along with four other genera for preserved secondary wood only and assign wood with a particular type of primary tissue (endarch primary xylem and large, non-septate homo or heterocellular pith without secretory cells) to Dadoxylon. This was done after comparison with the Type species first described by Lindley and Hutton in 1831.

Miller (1977) has stated that determining which woods of the late Palaeozoic and Mesozoic belong to Dadoxylon and which belong to Araucarioxylon is not an easy task and there is much confusion.

Erasmus (1976) states that according to the rule of priority the name Dadoxylon is the correct name and must be applied to both araucaroid Coniferales and cordaitalean woods.

I am in agreement with Maheshwari (1972) that secondary wood of the Dadoxylon and Araucarioxylon type which has well preserved primary tissue should be assigned to other taxa but see no point in retaining both Dadoxylon and Araucarioxylon for describing the same wood on the grounds of slight differences in the width of the rays. While it is true that recent Araucaria possesses uniseriate and rarely partly biseriate rays, it does not seem wise to use this as a criterion for dividing fossil woods which may be over 300 million years old.

It is suggested that the genus Araucarioxylon be dropped since it contradicts the botanical code of nomenclature, implying a direct relationship with living Araucaria and disregards the rule of priority as noted by Erasmus (1976).

Dadoxylon should be used for all secondary wood in which the primary tissues are not or are too poorly preserved to be used for taxonomic distinction. Those woods of Dadoxylon with preserved primary xylem and pith can be readily assigned to other taxa.

This will immediately remove any confusion between Dadoxylon and Araucarioxylon, which in point of fact was unnecessarily self-inflicted in the first place.

Fossil woods with Dadoxylom type secondary wood

Dadoxylon (no primary tissues)

| | |
|---|---|
| Damudoxylon Maheshwari 1966 | based on primary tissues. |
| Megaporoxylon Kräusel 1956 | |
| Kaokoxylon Kräusel 1956 | |
| Trigonomyelon Walton 1925 | |
| Solenoxylon Kräusel 1956 | |
| Polysolenoxylon Kräusel and Dolianti 1958 | |
| Antarcticoxylon Seward 1914 | |

In this list Dadoxylon corresponds to Araucarioxylon of Lepekhina (1972) and to Dadoxylon and Araucarioxylon combined in Maheshwari (1972).

Diagnosis of Dadoxylon, Endlicher 1847 emend. :

Homoxylic wood of gymnosperms. Growth rings more or less distinct or absent. Polygonal or round tracheid pits in uniseriate or multiseriate araucaroid arrangement, spiral thickenings are not present, cross-field pits araucaroid - cupressoid, numerous.

Rays, as a rule, uni - biseriate and rarely up to five seriate of various height. Horizontal and tangential walls of rays unpitted.

## SYSTEMATIC DESCRIPTION OF THE FLORA

The following qualitative and quantitative characters have been used wherever possible to fully describe the eleven specimens of fossil wood.

| Qualitative character | Corresponding quantitative character |
|---|---|
| * Growth rings | Size of rings and tracheids |
| Pith and cortical tissues | Size of pith and cortex |
| Xylem parenchyma | - |
| Resin production | - |
| Tangential tracheid pitting | Number of seriations, size of pits |
| * Type of radial tracheid pitting | * Number of seriations, size of pits |
| Bars of Sanio | - |
| * Type of cross-field pitting | * Number and size of pits |
| * Ray structure | * Height, width and cell dimensions |

An asterisk indicates the characters used for comparison purposes.

The wood descriptions are based on general observations of the blocks and the detail visible in transverse, tangential longitudinal and radial longitudinal sections. Additional information obtained by the use of the scanning electron microscope is also discussed.

### G.536.A

(Plates 15:56 and 15:57)

General observations: The block measures 7·0 centimetres long by 5·0 centimetres wide with prominent, thick ribbing on the external surface. The ribs measure 3 - 4 per centimetre and appear finely striated under the binocular microscope.

Transverse section: No cellular detail was visible, although possible growth rings (1·5 - 6·0 millimetres wide) were seen to correspond with the surface ribbing. No detail was visible in any longitudinal sections.

Scanning electron microscopy: Plate 15:57 illustrates the detail seen from a selected fractured, revealing the remains of tracheids ?. This is interesting as no cellular detail was seen in any sections.

G.536.B

(Plates 15:58 and 59, 16:60 - 64 and 17:65, Text Figures 45 and 47:A)

General observations: Block measures 5·6 centimetres long by 4·0 centimetres wide with prominent growth rings 0·8 - 2·0 millimetres thick and a finely striated weathered surface.

Transverse section: The early wood makes up the bulk of the growth ring, with the late wood restricted to a thickness of 45µm - 175µm and making up almost 10 % of a complete ring. The early wood tracheids measure from 26µm by 9·5µm to 49µm by 45µm in diameter and are commonly compressed tangentially. The late wood tracheids are much smaller, measuring from 3·5µm by 3·5µm to 7·5µm by 11·0µm in diameter.

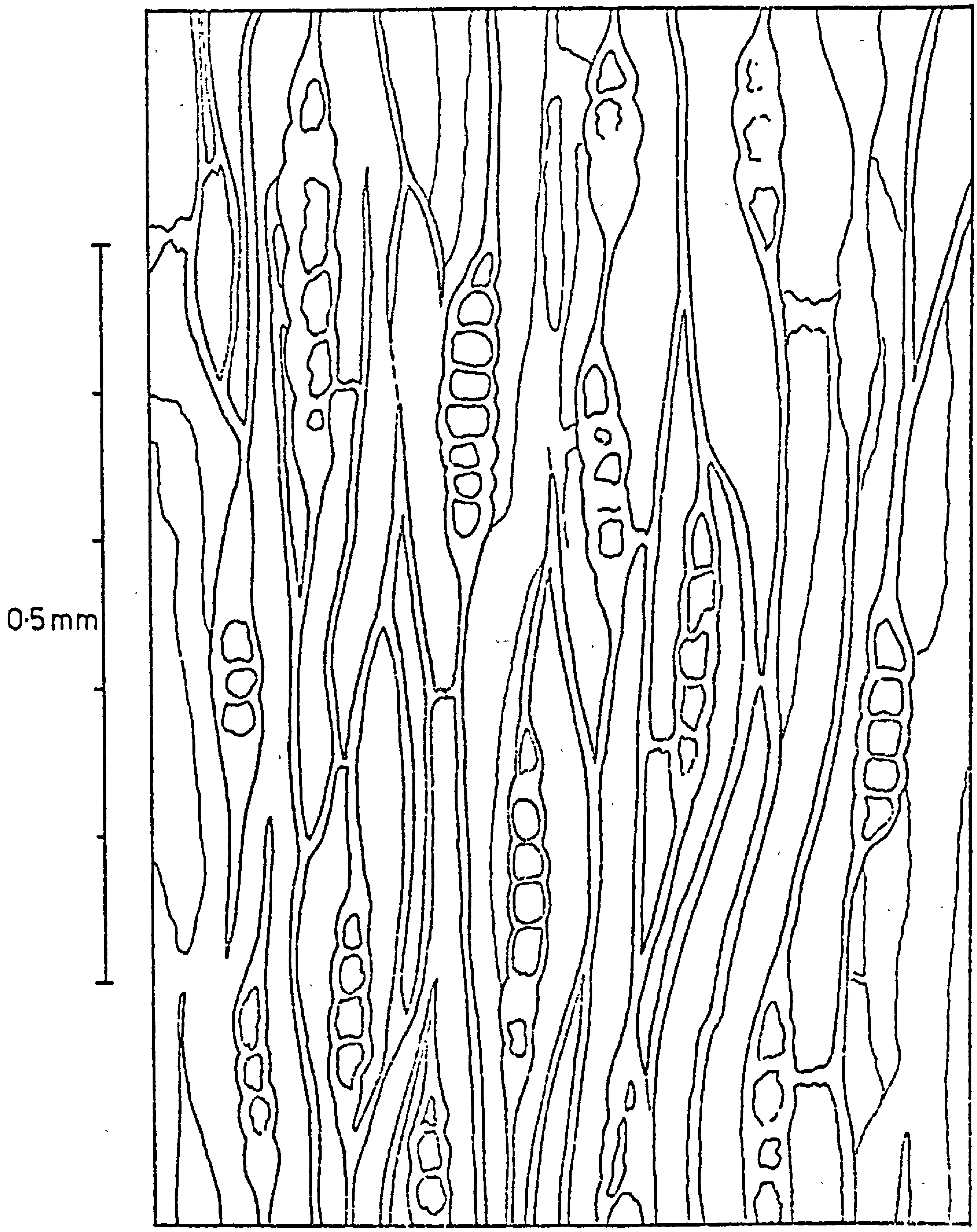
Tangential longitudinal section: The rays are uniseriate, measure 2 - 11 cells high and have an average height of between 4 - 6 cells. The rays are 60µm - 326µm in height, with middle cell measurements of 26µm by 15µm and wedge shaped end cell measurements of 15µm by 7·5µm in diameter.

Radial longitudinal section: The tracheids have lengths up to 650µm, with an average of 400µm and have uni - biseriate (rarely uniseriate) alternate bordered pitting. The pits range in size from 9·4µm by 8·6µm to 15µm by 11µm in diameter.

In the cross-field pitting, 2 - 8 pits (commonly 4 - 6) occured in each field, the pits being mostly round in shape, measuring 7·5µm by 7·5µm with simple, round to oval apertures 5·6µm by 5·0µm in diameter.

In many of the sections, tracheids were observed containing a darkly stained material (resin) which was often restricted to localized patches adjacent to the rays.

Scanning electron microscopy: Plate 16:63 illustrates a radially longit-




Text Figure 45: Wood B. Tangential longitudinal section. 830µm x 630µm area. Slide Number 4, Specimen Number G.536.B udinal fracture, revealing sections of uniseriate pitted tracheids and fragments of two rays.

Plate 17:64 illustrates a tangential longitudinal fracture which shows a vertical section through two rays. In the right hand ray, it is possible to see the individual cell walls of the ray members.

Plate 17:65 is an oblique transverse through two tracheids, the lowermost tracheid revealing biseriate pitting visible on the inner surface.

G.536.2

(Plates 17:67 and 18:68 - 70, Text Figures 46 and 47:B)

General observations: The wood block is 8·0 centimetres long by 3·7 centimetres wide with growth rings easily seen by the naked eye. No pith or cortical tissue was preserved.

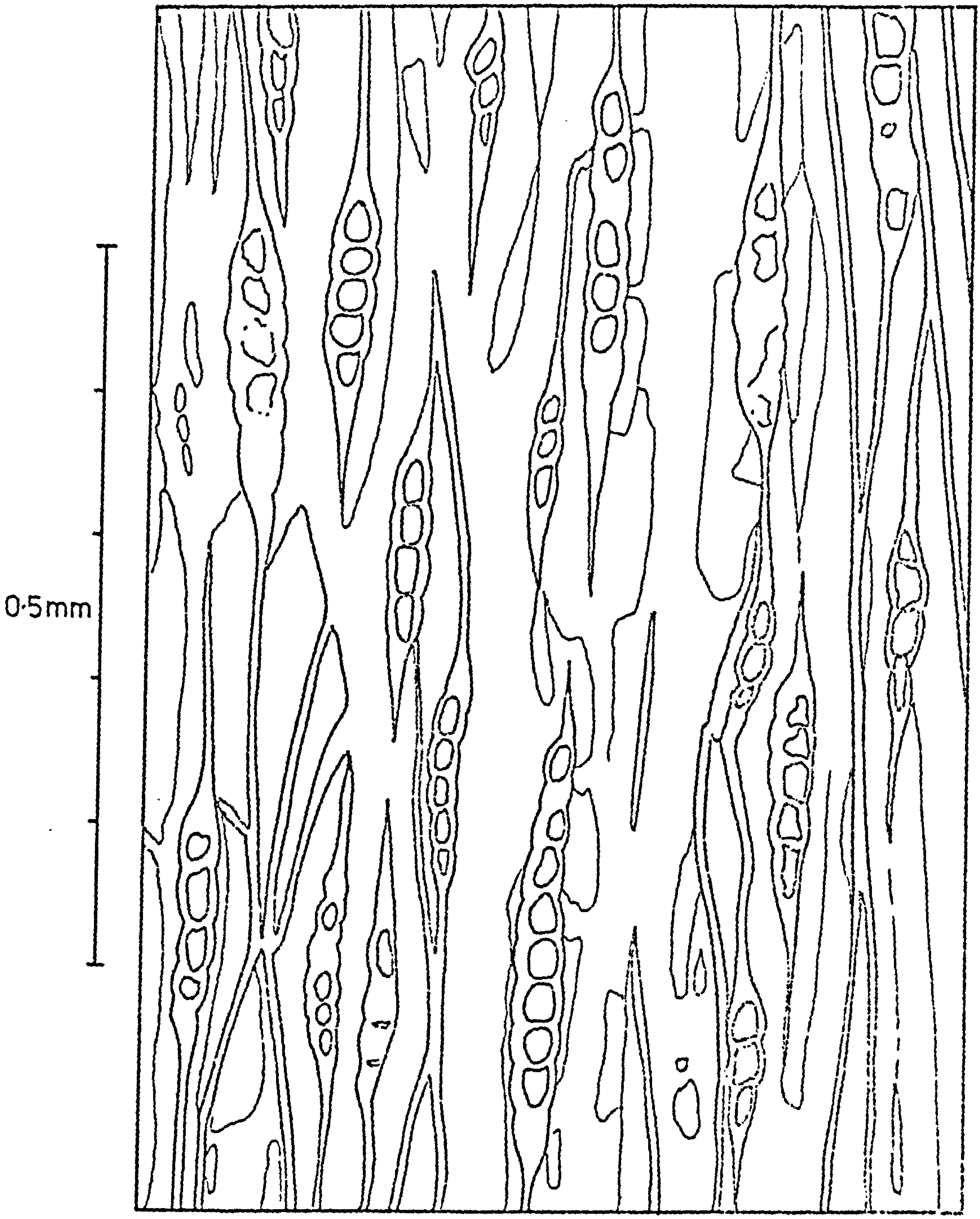
Transverse section: The growth rings are incomplete, measure 0·82 - 1·05 millimetres thick and composed mostly of early wood. The late wood measures 50µm - 125µm wide and makes up approximately 10 % of the growth ring. All of the tracheids are distorted (refer to Plates 17:67 and 18:68) to a certain degree and this has hindered direct measurements.

Early wood tracheids measure from 30µm by 22µm to 45µm by 38µm and late wood tracheids from 7·5µm by 6·0 µm to 11·1µm by 11·5µm in diameter.

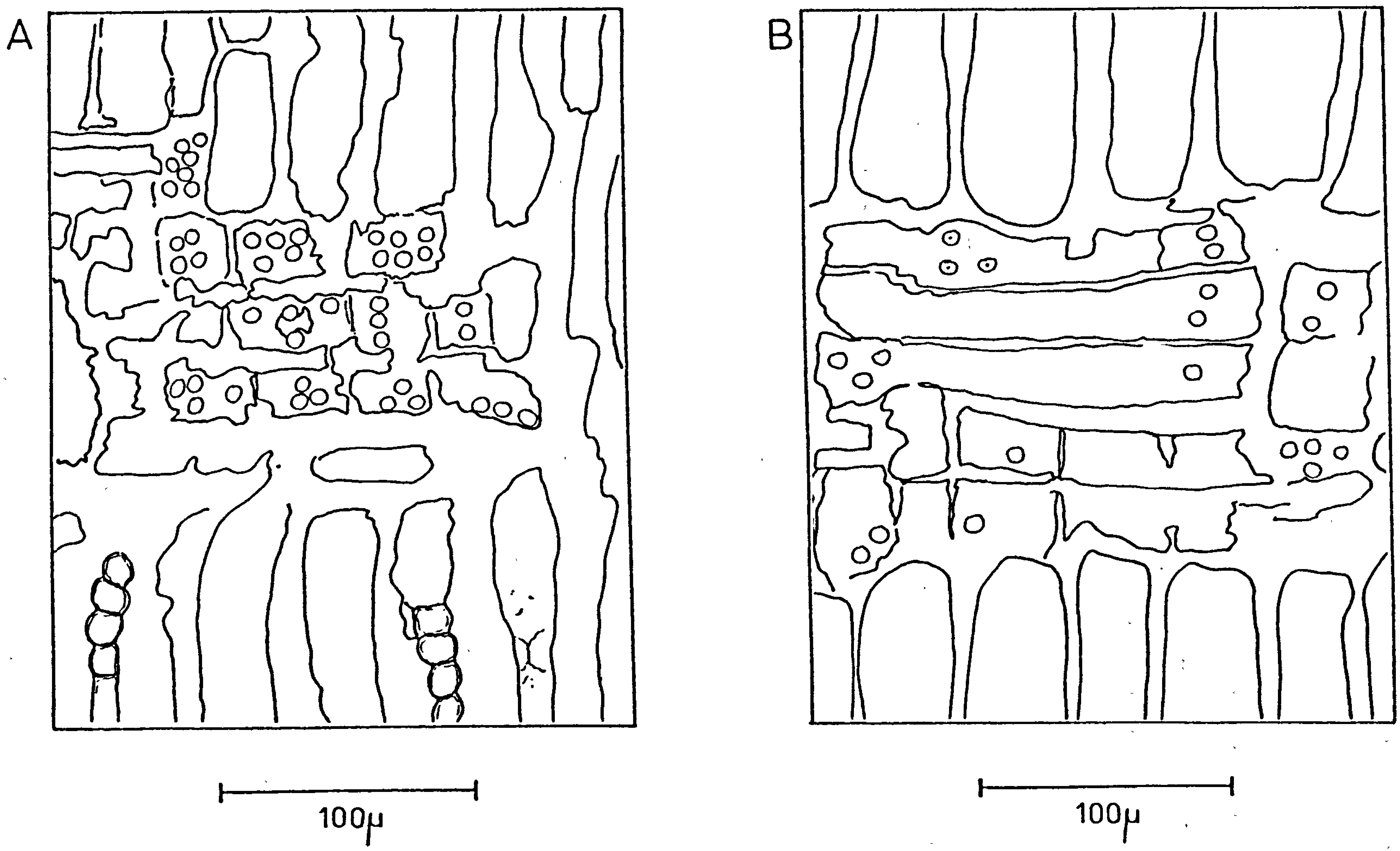
Tangential longitudinal section: Tangential pitting of the tracheids is not present, although radial pitting is sometimes seen owing to distortions in the wood.

The rays are all uniseriate and are 2 - 11 cells high (with an average height of 4 - 5 cells). The rays measure between 60µm and 390µm high, the middle cells measuring 22·6µm by 22·0µm and the wedge shaped end cells 22·6µm by 7·5µm in diameter.

Radial longitudinal section: Tracheids commonly measure from 350µm to 480µm in length, but some individual specimens appear to be up to 630µm long. The pitting on the radial walls of the tracheids is uni - triseriate




Text Figure 46: Wood 2. Tangential longitudinal section. 830µm x 630µm area. Slide Number 7. Specimen Number G.536.2




Text Figure 47: A. Wood B. Radial longitudinal section, revealing the cross-field pitting. Slide Number 2, Specimen Number G.536.B
B. Wood 2. Radial longitudinal section, revealing the cross-field pitting. Slide Number 6, Specimen Number G.536.2

(rarely uniseriate but commonly triseriate) with alternate bordered pitting. The overall pit size measures from 11•0µm by 9•5µm to 15•0µm by 12•0µm and the pit pore, which was preserved in only a few cases measure from 7•5µm by 7•0µm to 10•5µm by 8•3µm in diameter.

One to four pits are found in the cross-field and in some cases a paired arrangement can be discerned. The pits have an overall measurement from 6•6µm by 6•6µm to 10•0um by 7•5µm with pit pores 5•2µm by 5•2µm to 7•5µm by 5•6µm in diameter.

From various sections, it would appear that localized patches of resin are present as many tracheids have darkly stained contents.

Surprisingly, results with the scanning electron microscope on wood fractures proved disappointing in view of the fact that the material had provided good peel sections.

<u>G.536.3</u>

(Plate 18:71)

<u>General observations</u>: The material consisted of a compressed axis on the surface of a large rock specimen. The axis measured 8•5 centimetres long (although wood was only preserved over a length of 5•2 centimetres) by 1•7 centimetres wide and was up to 2•0 millimetres thick. Fine ribbing could be seen on the surface of the axis and may represent the remains of growth rings.

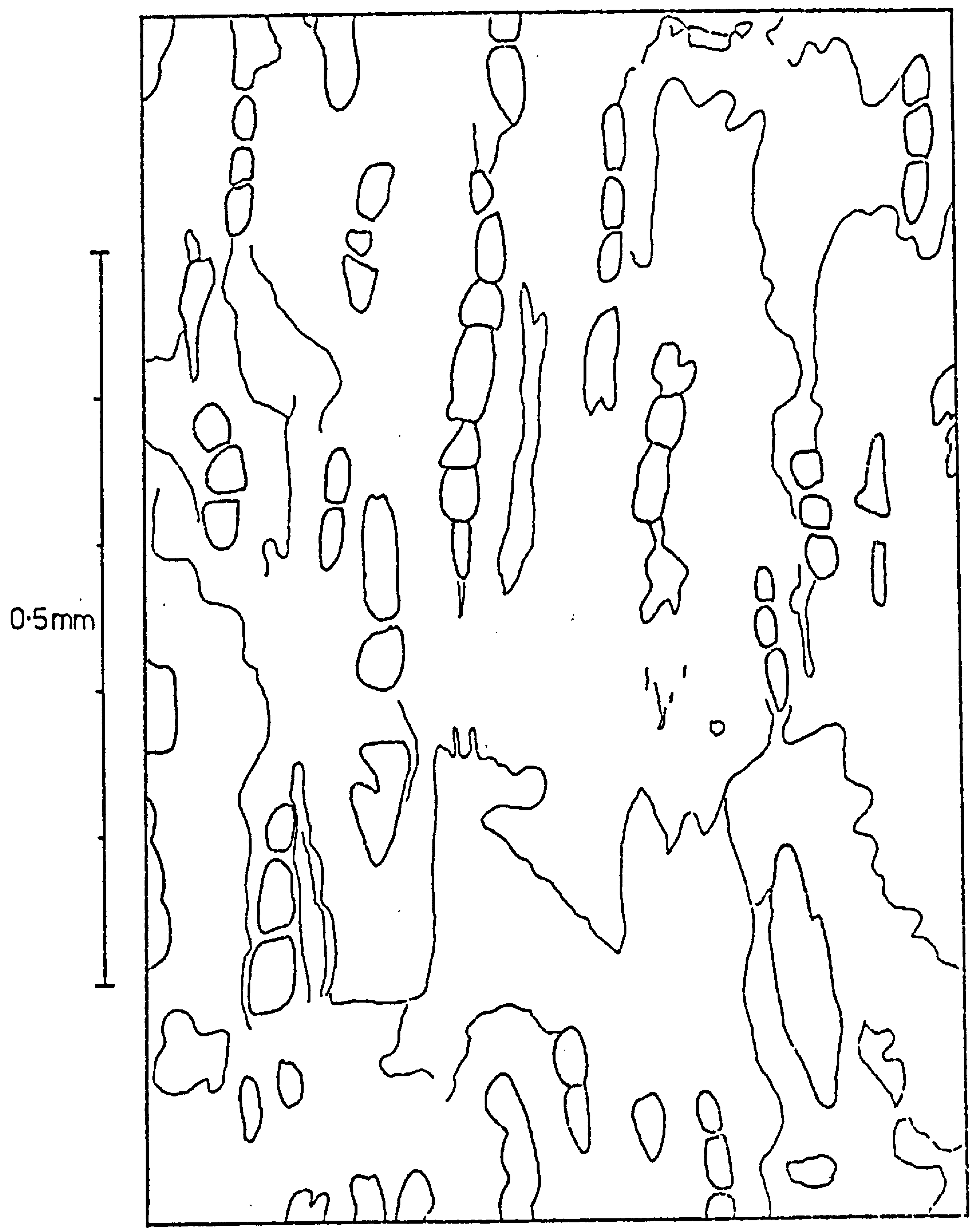
A series of peels was made from the surface of the specimen and selected areas mounted on slides. The preservation was extremely poor, all of the the cells having been broken down and preventing any microscopic details being recorded.

No other sections were taken.

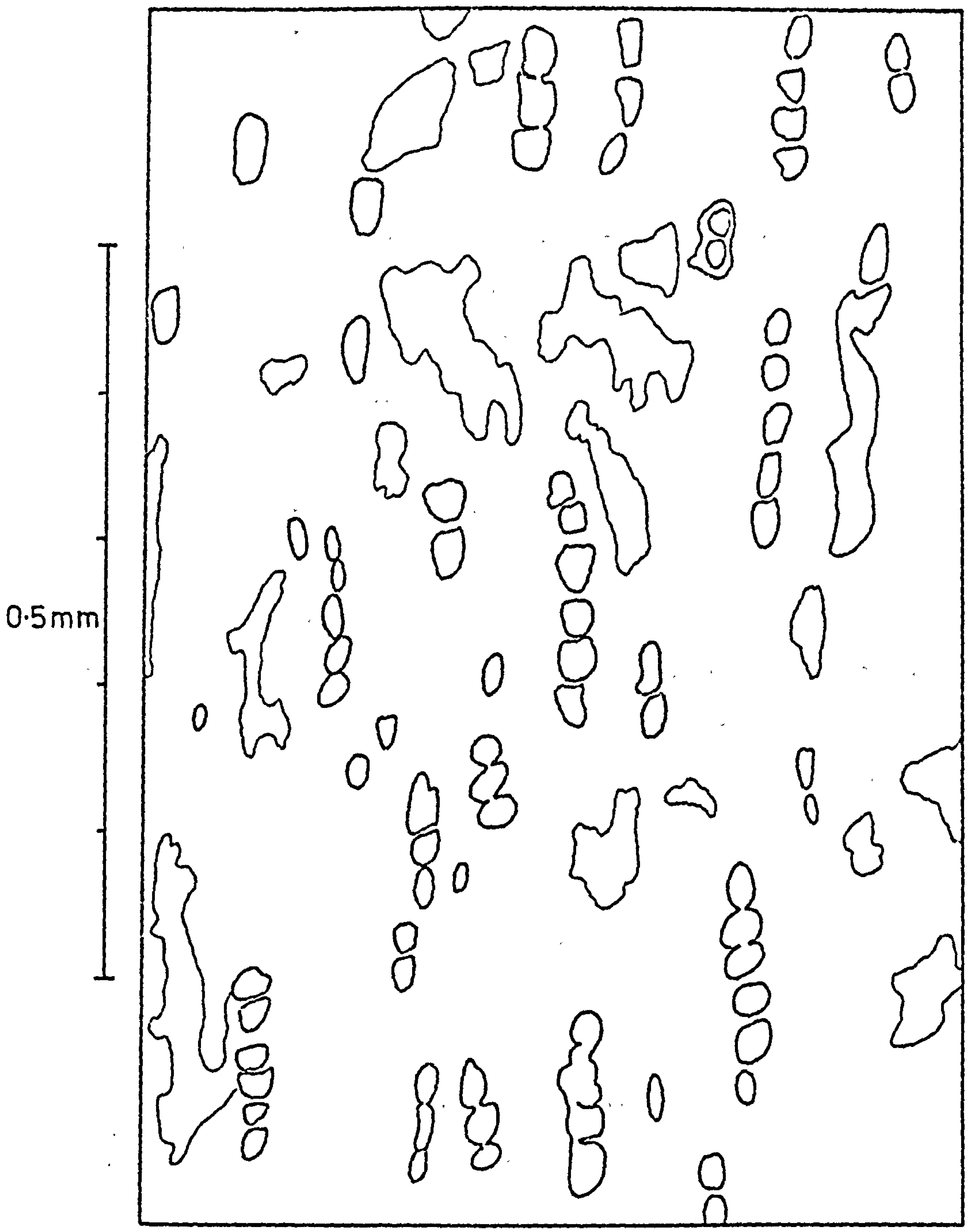
<u>G.536.4 and 8</u> (part and counterpart)

(Plates 20:79 and 21:80 - 82, Text Figures 48 and 49)

<u>General observations</u>: Specimen G.536.4 is a wood block 7•0 centimetres long by 4•7 centimetres wide with prominent mineral banding of lignite




Text Figure 48: Wood 4. Tangential longitudinal section. 830μm x 630μm area. Slide Number 9. Specimen Number G.536.4




Text Figure 49: Wood 8. Tangential longitudinal section. 830μm x 630μm area. Slide Number 17. Specimen Number G.536.8

and iron oxide and only a faint suggestion of growth rings.

Specimen G.536.8 measured 4·9 centimetres long by 4·75 centimetres wide and also possessed the mineral banding and poor growth rings.

The complete specimen (G.536.4 and G.536.8) measures 7·6 centimetres long by 5·7 centimetres wide.

Transverse section: G.536.4. No growth rings seen under microscope and very few tracheids preserved, some with apparent diameters of 15·0μm. G.536.8. Slightly better preservation was encountered with tracheids measuring from 15·0μm by 7·5μm to 30·0μm by 22·6μm in diameter with a very pronounced tangential compression and a suggestion of growth rings.

Tangential longitudinal section: G.536.4. All rays uniseriate, 2 – 8 cells high with an average height of 4 – 5 cells. The rays measure from 25·0μm to 290μm high with the middle cells measuring 33·0μm by 30·0μm to 37·5μm by 37·5μm and the edge cells 21·0μm by 19·0μm in cross section. G.536.8. All rays uniseriate, 2 – 13 cells high with an average height of 3 – 5 cells. The rays measure from 90·0μm to 587μm high with the middle cells measuring 45·0μm by 45·0μm and the edge cells 45·0μm by 37·0μm in cross section.

Tangential pitting was not observed in either specimen.

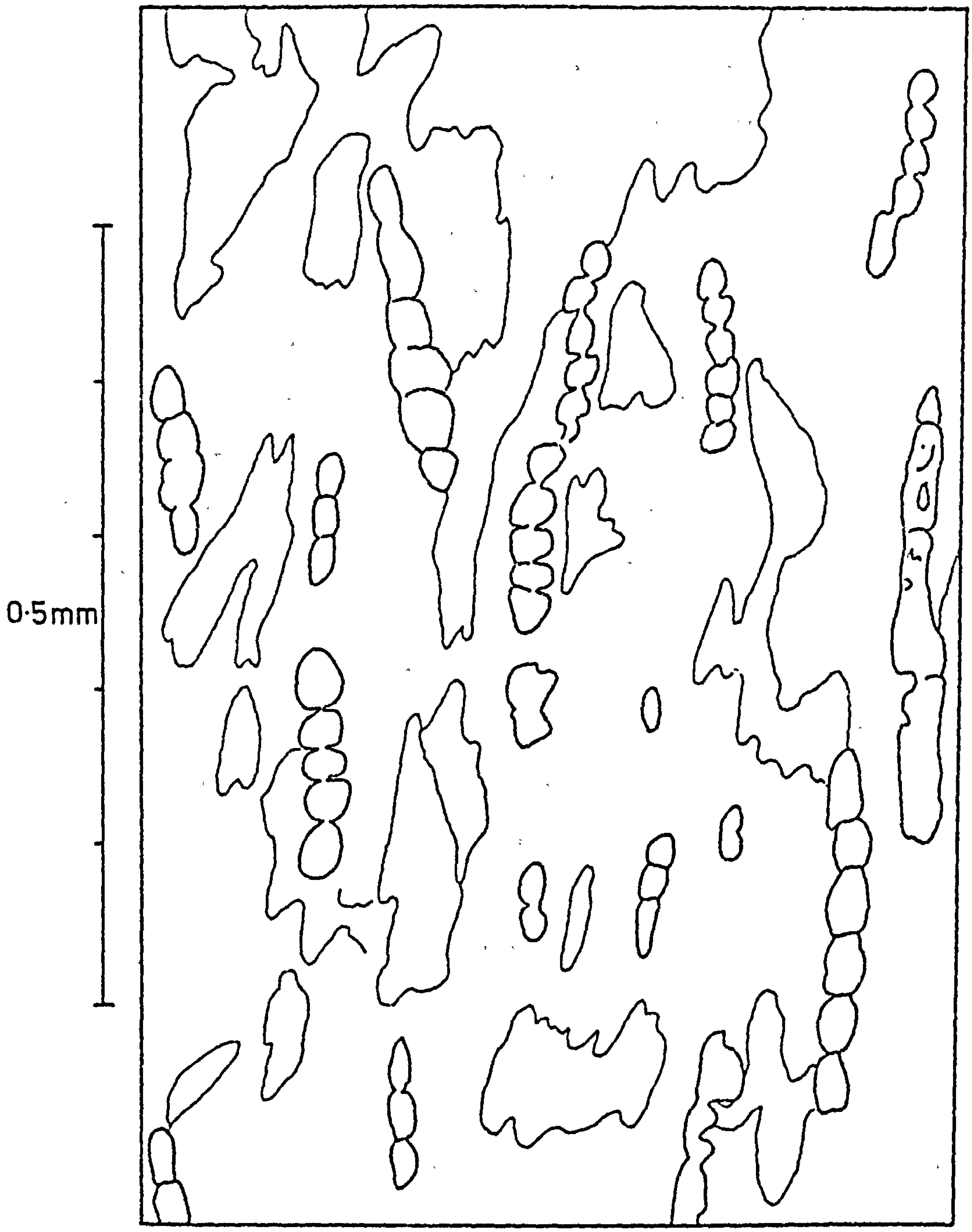
Radial longitudinal section: G.536.4. The tracheids appear to have uniseriate pitting with individual pits measuring 10·5μm by 7·5μm in diameter. In G.536.8 both uniseriate and biseriate pitting was preserved, with pits 9·4μm by 5·0μm to 9·4μm by 8·6μm in diameter and round pit pores 4·8μm by 4·8μm in size.

In both specimens the cross-field pitting is poorly preserved, although in a few examples in G.536.8 one to four pits (possibly in pairs) can just be made out. The pits appear to measure 6·0μm by 4·5μm in diameter.

G.536.6

(Plates 19:72 – 75 and 20:76, Text Figure 50)

General observations: The block measures 4·7 centimetres long by 1·6




Text Figure 50: Wood 6. Tangential longitudinal section. 830μm x 630μm area. Slide Number 13. Specimen Number G.536.6

centimetres wide with no apparent growth rings.

Transverse section: The growth rings can be seen to measure 1·0 - 3·3 millimetres thick, with individual tracheids ranging in size from 15·0µm by 15·0µm to 38·0µm by 36·5µm and many appear to contain darkly stained material and which is probably the remains of resin. In some tracheids the cell wall (ie. probably two cell walls) is over 5·0µm thick.

Tangential longitudinal section: The rays are uniseriate, 2 - 10 cells high with an average height of 3 - 4 cells. The rays measure 80·0µm to 360µm high with the middle cells measuring 30·0µm by 30·0µm and the edge cells 30·0µm by 25·0µm in cross section.

Radial longitudinal section: The tracheids measure between 150µm and 225µm long, although some appear to have lengths up to 489µm and possess uni - biseriate (mostly uniseriate) bordered pitting. In contiguous uniseriate pitting the pits measure 11·0µm by 5·5µm in diameter.

The cross-field pitting was poorly preserved and it appeared that maybe 1 - 2, possibly more pits occured in each field.

In all of the sections made, there was no evidence of any tangential pitting.

G.536.7

(Plates 20:77 and 20:78)

General observations: The block measured 4·1 centimetres long by up to 3·0 centimetres wide with no apparent external detail visible.

Transverse section: Although no growth rings were observed the tracheids ranged in diameter from 13·2µm by 11·3µm to 23·0µm by 15·0µm.

No details were visible in any of the longitudinal sections.

Examination of fractured surfaces by binocular microscope revealed rays up to 18 cells high (more commonly 5 - 7) and these appeared to be uniseriate but this is not conclusive. It was hoped that the scanning electron microscope would provide more information about this material but, as with much of the other wood, results were disappointing.

G.536.9

(Plate 21:83)

General observations: The block measures 8·7 centimetres long by 6·8 centimetres wide with a very finely striated outer surface and possible growth rings 0·6 - 4·0 millimetres thick.

Both transverse and longitudinal sections were prepared but revealed the specimen to be very poorly preserved and hence no microscopic details could be recorded.

G.536.13

(Plate 22:84 - 86)

General observations: This large specimen measures 9·5 centimetres long by up to 9·0 centimetres wide with a central hole which is probably not an original feature as the growth rings (0·5 - 2·0 millimetres thick) do not give the impression that the hole marks the centre.

The preservation is identical to that seen in the previous specimen and thus did not allow any microscopic information to be recorded from any of the sections.

Examination of the external surface by binocular microscope revealed a striated pattern and this was also observed in some fractured material but no extra information could be obtained.

Better results were produced by the examination of fractured material by the scanning electron microscope (refer to Plates 21:85 and 86) where the detail of the tracheid pitting (bi - triseriate) is visible in both low and higher magnification. This cellular detail is suprising as no evididence of cellular preservation was seen in any of the peel sections. This supports the view that the scanning electron microscope can fulfil a role as an important tool in research, particularly in the field of palaeobotany.

G.536.14

(Plate 22:87)

General observations: The large block measures 10 centimetres long by up

10·5 centimetres wide and 3·1 centimetres thick. The specimen has very prominent surface ribbing, with 2 - 4 ribs per centimetre and is similar to G.536.A.

Transverse section: No cellular detail was visible but possible growth rings were seen and may correspond with the external ribbing pattern.

No detail was observed in any longitudnal section or on the examination of fractured material by binocular or scanning electron microscopes.

| SPECIMEN NUMBER | GROWTH RINGS | TRACHEID PITTING | RAY WIDTH | RAY HEIGHT | CROSSFIELD PITTING | XYLEM PAREN. | RESIN TRACHEIDS | BARS OF SANIO | CORTEX/ PITH |
|---|---|---|---|---|---|---|---|---|---|
| G.536.A | Distinct | – | – | – | – | – | – | – | Absent |
| G.536.B | " | 1 – 2 (2) | Uniseriate | 2 – 11 (4 – 6) | 2 – 8 | Absent | Present | Absent | " |
| G.536.2 | " | 1 – 3 (3) | " | 2 – 11 (4 – 5) | 1 – 4 | " | " | " | " |
| G.536.3 | Possible | – | – | – | – | – | – | – | " |
| G.536.4 | Faint | 1 | Uniseriate | 2 – 8 (4 – 5) | – | Absent | Absent | Absent | " |
| G.536.6 | Distinct | 1 – 2 (1) | " | 2 – 10 (3 – 4) | 1 – 2? | " | Traces? | " | " |
| G.536.7 | Absent | – | " ? | up to 18 (5 – 7?) | – | – | – | – | " |
| G.536.8 | Present | 1 – 2 (1) | " | 2 – 13 (3 – 5) | 1 – 4? | Absent | Absent | Absent | " |
| G.536.9 | Distinct | – | – | – | – | – | – | – | " |
| G.536.13 | " | 2 – 3 (?) | – | – | – | – | – | – | " |
| G.536.14 | " | – | – | – | – | – | – | – | " |

Table 15. Results of wood study

## COMPARISONS.

Comparisons have been made with approximately one hundred species of Dadoxylon from Palaeozoic, Mesozoic and Tertiary deposits from both the northern and southern hemispheres. This list is not complete and as well as some species which may have been overlooked, there are several absentees owing to the unavailability of the relevant published works.

Many of the older references provide incomplete diagnoses and this severely restricts their usefulness in comparison studies.

Table 15 lists the results of the wood studied from King George Island and there would appear to be at least three distinct taxa which warrant a more detailed study. These are G.536.B, G.536.2 and a combination of G.536.4 and 8 with G.536.6 which seem to be identical (see Table 16).

All of these well preserved specimens possess growth rings, have uniseriate rays only (no trace of even a partly biseriate ray has been detected) and the height of the rays do not exceed 13 cells.

Table 16

| Number | Growth rings | Tracheid pitting | Ray height | X-field pitting |
|---|---|---|---|---|
| G.536.B | Distinct | 1 - 2 (2) | 2 - 11 (4 - 6) | 2 - 8 |
| G.536.2 | Distinct | 1 - 3 (3) | 2 - 11 (4 - 5) | 1 - 4 |
| G.536.4/6/8 | Distinct | 1 - 2 (1) | 2 - 13 (3 - 5) | 1 - 2 - 4 ? |

Disregarding the presence or absence of growth rings, there are five Palaeozoic and seventeen Mesozoic and Tertiary species which have uniseriate rays up to 15 cells high and which show some similarities with the the above taxa (refer to Tables 17 and 18).

Palaeozoic comparisons: None of the five dadoxyla with uniseriate rays compares exactly with any of the three King George Island taxa. In most

| SPECIES | REFERENCE | GROWTH RINGS | TRACHEID PITTING | RAY WIDTH | RAY HEIGHT | CROSSFIELD PITTING |
|---|---|---|---|---|---|---|
| Dadoxylon abaschevskiense | Lepekhina (1969) | Distinct | 1 – 5 | Uniseriate | 1 – 5 (1 – 2) | 6 – 12 |
| " acadium | Penhallow (1900) | Indistinct | 2 – 5 | Uni-biseriate | up to 60 | 4 – 10 |
| " allani | Kräusel (1962) | Distinct | 1 – 2 | Uni-p. biseriate | 1 – 12 (2 – 5) | 1 – 8 |
| " angustum | Halle (1912) | Indistinct | 2 – 3 | Uni-v.r.p.biseriate | 1 – 25 | 2 – 5 |
| " anulatum | Penhallow (1900) | " | 1 – 3 | – | – | – |
| " arberi | Beeston (1972) | Distinct | 1 – 4 | Uni-p. biseriate | 1 – 11 (2 – 5) | 2 – 10 |
| " bajdaevkaense | Lepekhina (1972) | " | 1 – 3 | Uni-r.p. biseriate | 1 – 5 (1 – 2) | 2 – 16 |
| " balachonskiense | Lepekhina (1972) | " | 1 – 3 | Uni-r.p. biseriate | 1 – 10 (1 – 8) | 2 – 10 |
| " barakarense | Surange & Saxena (1958) | " | 1 – 3 | Uni-biseriate | 1 – 22 (13) | 2 – 5 |
| " bengalense | Holden (1917) | " | 1 – 3 | Uniseriate | 1 – 20 (6 – 7) | 2 – 7 |
| " biarmicum | Zalessky (1927) | " | 1 – 3 | Uni-v.r.p.biseriate | 1 – 42+ | 1 |
| " bougheyi | Williams (1966) | " | 1 – 4 | Uni-p. biseriate | 1 – 66 (7) | 2 – 6 |
| " conforme | Lepekhina (1972) | " | 1 – 5 | Uni-p. biseriate | 1 – 20 (15) | 2 – 16 |
| " douglasense | Steidtmann (1934) | Indistinct | 1 – 3 | Uni-p. biseriate | 1 – 40 (10 – 20) | 1 – 5 |
| " erunakovskiense | Lepekhina (1972) | Distinct | 1 – 5 | Uniseriate | 1 – 20 (17) | 2 – 30 |
| " gondwanense | Maithy (1965) | " | 1 – 5 | Uni-p. biseriate | 1 – 43 (8 – 9) | 2 – 8 |
| " gorelovae | Lepekhina (1972) | " | 1 – 5 | Uni-biseriate | 1 – 30 (20) | 4 – 14 |
| " heteromorphum | Lepekhina (1972) | " | 1 – 2 | Uni-p. biseriate | 1 – 20 (1 – 10) | 2 – 10 |
| " humiliradiale | Lepekhina (1972) | " | 1 – 3 | Uniseriate | 1 – 7 (1 – 5) | 3 – 12 |
| " hoegii | Lepekhina (1972) | – | 1 – 2 | Uni-biseriate | 1 – 22 (10) | 5 – 10 |
| " iniaense | Lepekhina (1972) | Distinct | 1 – 4 | Biseriate | 1 – 16 (10) | 2 – 10 |
| " jamudhiense | Maheshwari (1964) | Indistinct | 1 – 3 | Uni-p. biseriate | 1 – 18 (5 – 6) | 1 – 4 |
| " kharkhariense | Maithy (1965) | Distinct | 1 – 3 | Uni-r.p. biseriate | 1 – 29 (6 – 7) | 2 – 7 |
| " kuznetzkense | Lepekhina (1969) | " | 1 – 5 | Uni-biseriate | 1 – 16 (12) | 8 – 20 |
| " leei | Sze (1952) | Indistinct | 1 – 2 | Uniseriate | 1 – 22 (6) | 1 |
| " lukugense | Grambast (1960) | Distinct | 1 – 2 | Uni-biseriate | 1 – 62 (2 – 3) | 3 – 8 |
| " manieroi | Kräusel & Dolianiti (1958) | " | 1 – 4 | – | 1 – 49 (9 – 10) | 1 – 9 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Dadoxylon materiarium | Steidtmann (1934) | Indistinct | 2 – 4 | Uni-p. biseriate | up to 40 | 1 – 5 |
| " matrioide | Penhallow (1900) | " | 1 – 3 | Uni-p. biseriate | 35+ | 1 – 8 |
| " meridionale | White (1908)- | " | 1 | Uni-r. biseriate | 1 – 30 | 1 – 4 |
| " monoseriale | Lepekhina (1972) | Distinct | 1 – 4 | Uniseriate | 1 – 27 (15) | 2 – 16 |
| " multiseriale | Lepekhina (1972) | " | 1 – 6 | Uni-r.p. biseriate | 1 – 10 (8) | 4 – 20 |
| " ndundense | Smith (1975) | Indistinct | 1 – 2 | Uni-p. biseriate | 1 – 24 (2 – 4) | 1 – 7 |
| " ningahense | Maheshwari (1965) | Distinct | 1 – 4 | Uni-r.p. biseriate | 1 – 11 (2 – 3) | 1 – 6 |
| " nummularium | White (1908) | Indistinct | 1 – 2 | Uni-biseriate | 1 – 30 (6 – 7) | 1 – 6 |
| " ohioense | Penhallow (1900) | " | 2 – 4 | Uni-triseriate | 25+ | 2? |
| " originale | Lepekhina (1972) | Distinct | 1 – 5 | Uni-r.p. biseriate | 1 – 12 (7) | 2 – 12 |
| " parbeliense | Rao (1935) | " | 1 – 5 | – | 1 – 24 (2 – 3) | 8 – 9 |
| " permicum | Zalessky (1927) | Indistinct | 1 – 2 | Uniseriate | 1 – 19+ | 1 – 5 |
| " polyporosum | Lepekhina (1969) | Distinct | 1 – 5 | Uni-biseriate | 1 – 15 (1 – 10) | 7 – 20 |
| " proceriradiale | Lepekhina (1969) | " | 1 – 6 | Uni-r.p. biseriate | 1 – 30 | 4 – 20 |
| " rangeiforme | Lepekhina (1972) | " | 1 – 5 | Uniseriate | 1 – 8 (5) | 3 – 13 |
| " recentium | Penhallow (1900) | Indistinct | 1 | Uni-biseriate | – | pits in row |
| " rollei | Unger (1859) | " | 1 – 3 | Uni-p. biseriate | 2 – 40 | – |
| " romingerianum | Arnold (1931) | " | 2 – 5 | Uni-p. biseriate | 2 – 40 (20) | 1 – 2 |
| " roxoi | Maniero (1946) | Distinct | 1 – 2 | Uni-v.r.p.biseriate | 1 – 20 (7) | 2 – 6 |
| " sibiricum | Lepekhina (1972) | " – | 1 – 4 | Uniseriate | 1 – 6 (3) | 2 – 12 |
| " simile | Lepekhina (1972) | " | 1 – 4 | Uni-biseriate | 1 – 20 (1 – 18) | 2 – 20 |
| " spirale | Greguss (1967) | Indistinct | 1 – 2 | Uniseriate | 1 – 10 | 2 – 4 |
| " subprotopityoides | Lepekhina (1969) | Distinct | 1 – 3 | Uni-biseriate | 1 – 5 | 2 – 7 |
| " tchertense | Lepekhina (1969) | " | 1 – 4 | Uni-biseriate | 1 – 10 | up to 23 |
| " transiense | Lepekhina (1972) | " | 1 – 3 | Uni-p. biseriate | 1 – 13 (1 – 10) | 2 – 16 |
| " weaverense | Maheshwari (1972) | " | 1 – 4 | Uni-biseriate | 1 – 21 (7) | 1 – 7 |
| " yavorskyi | Lepekhina (1972) | " | 1 – 4 | Uni-r. biseriate | 1 – 13 (1 – 6) | 2 – 20 |

Table17. Palaeozoic woods of Dadoxylon

| SPECIES | REFERENCE | GROWTH RINGS | TRACHEID PITTING | RAY WIDTH | RAY HEIGHT | CROSSFIELD PITTING |
|---|---|---|---|---|---|---|
| Dadoxylon agathoides | Kräusel & Jain (1964) | Distinct | 1 – 3 | Uni-p. biseriate | 2 – 20 (8) | 2 – 8 |
| " alpinum | Lemoigne (1966) | Indistinct | 1 – 2 | Uniseriate | 2 – 12 (8 – 10) | 1 – 3 |
| " amraparense | Sah & Jain (1964) | Distinct | 1 – 3 | Uniseriate | 1 – 15 (6) | 4 – 8 |
| " arduennense | Lemoigne & Demarq (1967) | " | 1 – 3 | Uni-tetraseriate | 4 – 80 | 2 – 4 |
| " australe | Edwards (1934) | " | 1 – 4 | Uniseriate | 1 – 15 | 3 – 12 |
| " barremianum | Fliche (1900a) | " | 1 – 2 | Uniseriate | 2 – 11 (2 – 5) | – |
| " bindrabunense | Sah & Jain (1964) | Indistinct | 1 – 3 | Uniseriate | 1 – 45 (25) | 4 – 12 |
| " bondii | Williams (1966) | Distinct | 1 – 2 | Uniseriate | 1 – 17 (4) | 2 – 10 |
| " boureaui | Lanteaume (1950) | " | 1 – 3 | Uni-r. biseriate | 4 – 45 (10 – 22) | 1 – 2 |
| " breveradiatum | Seward (1919) | – | 1 – 3 | Uniseriate | 1 – 3 (v.r. 4) | 8 – 15 |
| " catuanense | Smith (1975) | Indistinct | 1 | Uniseriate | 1 – 14 (2 – 4) | 3 – 6 |
| " chevalieri | Boureau (1950) | Distinct | 1 | Uniseriate | 2 – 12 (4 – 6) | 3 – 6 |
| " chhindwarensis | Billimoria (1948) | " | 1 – 3 | Uni-biseriate | – | 1 – 7 |
| " dalloni | Boureau (1948a) | Indistinct | 1 – 2 | Uniseriate | 2 – 20 | 1 – 4 |
| " deccani | Shukla (1938) | Distinct | 1 – 2 | Uniseriate | 2 – 49 (18) | 1 – 6 |
| " divescence | Seward (1919) | – | 1 – 4 | – | 8 – 11 | – |
| " eocenum | Chitaley (1949) | Distinct | 1 – 3 | Uni-p. biseriate | 1 – 15 | 1 – 7 |
| " japonicum | Shimakura (1936) | " | 1 – 3 | Uni-r. biseriate | 1 – 24 (3 – 10) | 1 – 14 |
| " kaiparaense | Edwards (1926) | " | 1 – 3 | Uniseriate | 1 – 8 (2 – 3) | 1 – 10 |
| " kerguelense | Edwards (1921) | " | 1 – 2 | Uniseriate | 1 – 11 | 5 – 9 |
| " keuperianum | Seward (1919) | – | 1+ | Uniseriate | 2 – 50 | 2 – 4 |
| " lugriense | Boureau (1948b) | Indistinct | 1 – 2 | Uniseriate | 1 – 17 | up to 16 |
| " madagascariense | Fliche (1900b, 1905) | Distinct | 1 – 2 | Uniseriate | 5 – 22 (3 – 8) | – |

| | | | | | | |
|---|---|---|---|---|---|---|
| Dadoxylon mahajumbjense | Fliche (1905) | Distinct | 2 | Uniseriate | 8 – 16 | small |
| " mandroense | Sah & Jain (1964) | " | 1 – 3 | Uniseriate | 1 – 15 (3 – 4) | 2 – 12 |
| " mecsekense | Greguss (1967) | " | 1 – 3 | Uniseriate | 1 – 15 | 8 – 10 |
| " mohgaensis | Lakhampal et al (1977) | " | 1 – 3 | Uniseriate | 2 – 30 (8 – 15) | 1 – 2 |
| " novae – zeelandii | Stopes (1914) | " | 2 | Uniseriate | 1 – 7 (3 – 4) | 5 – 6 |
| " pseudoparenchymatosum | Gothan (1908) | " | 1 – 2 | Uni-r.p.biseriate | 2 – 10 | 2 – 6 |
| " rajmahalense | Suryanarayama (1955) | " | 2 – 3 | Uniseriate | 1 – 20 (5) | – |
| " resiniferum | Greguss (1967) | Indistinct | 1 – 2 | Uni-biseriate | 1 – 8 (1 – 6) | – |
| " resinosum | Shukla (1944) | Distinct | 1 – 4 | Uni-p. biseriate | 1 – 39 | 1 – 10 |
| " santalense | Sah & Jain (1964) | " | 1 – 2 | Uniseriate | 1 – 10 (4 – 5) | 2 – 6 |
| " septatum | Boureau (1951) | Indistinct | 1 – 2 | Uniseriate | 1 – 7 (2 – 3) | 1 – 3 |
| " septentrionale | Seward (1919) | Distinct | 1 – 2 | Uniseriate | 1 – 30 | 2 – 4 |
| " shuklai | Singhai (1958) | " | 1 – 3 | Uni-biseriate | 1 – 28 (2 – 10) | 1 – 4 |
| " sidugawaense | Shimakura (1936) | " | 1 – 2 | Uni-r.p.biseriate | 1 – 14 (3 – 10) | 1 – 2 |
| " tankoense | Stopes & Fujii (1910) | " | 2 – 5 | Uniseriate | 3 – 6 | – |
| " teixeira | Boureau (1949) | Indistinct | 1 – 2 | Uni-biseriate | 3 – 18 | 6 – 12+ |
| " trachanti | Lignier (1907) | Distinct | 1 – 2 | Uniseriate | 1 – 19 (2 – 5) | up to 4 |
| " vanartsdaleni | Wherry (1912) | Indistinct | 1 – 2 | – | 1 – 10 (5 – 6) | – |
| " virginianum | Wherry (1912) | " | 1 – 2 | Uniseriate | 1 – 27 (10 – 12) | – |
| " wyomingense | Andrews & Pannel (1942) | " | 1 – 2 | Uniseriate | 1 – 3 | cupressoid |
| " zuffardii | Negri (1914) | " | 2 – 4 | Uniseriate | 1 – 7 | – |
| " sp. | Holden (1913) | – | 2 | – | – | – |

Table 18. Mesozoic and Tertiary woods of Dadoxylon

cases the tracheidal pitting on the radial walls is up to 4 - 5 seriate, the rays are fairly short (less than 8 cells high) and up to 12 - 13 pits occur in each cross-field.

Dadoxylon spirale (Greguss, 1967) is the closest comparison, with uni - biseriate tracheidal pitting, rays 1 - 10 cells high and 2 - 4 pits per cross-field. It differs in that growth rings are indistinct and that spiral thickenings occur in the tracheids.

Mesozoic and Tertiary comparisons: G.536.B. This wood compares with Dadoxylon kaiparaense, Dadoxylon kerguelense and Dadoxylon novae zeelandii. Although treated as separate species for comparison purposes, these three species are all included as synonyms of Dadoxylon pseudoparenchymatosum first described by Gothan (1908) from Seymour Island, Antarctica (refer to Table 19).

In Dadoxylon pseudoparenchymatosum growths rings are distinct, the tracheids have 1 - 2 seriate pitting, the rays are uniseriate and 1 - 11 cells high and 1 - 10 pits occur per cross-field. Resin tracheids are commonly found adjacent to the rays although its concentration and distribution do vary slightly.

These characters compare almost exactly with those of G.536.B.

Seward (1919) states that in Dadoxylon kerguelense the growth rings are 15 - 20 tracheids broad and the later wood is represented by only two rows of elements (approximately 10 % of the ring) and this is exactly as is found in G.536.B.

Gothan (1908) states that in Dadoxylon pseudoparenchymatosum the pits on the tracheids measure from 10µm to 12µm in diameter and compares with measurements of 9·4µm by 8·6µm to 15·0µm by 11·0µm made from G.536.B.

There seems to be little doubt that the wood described under G.536.B should be included in Dadoxylon pseudoparenchymatosum Gothan.

Florin (page 37, 1940) states that Dadoxylon pseudoparenchymatosum represents the wood of sect. Colymbea of Araucaria .

| SPECIES | REFERENCE | GROWTH RINGS | TRACHEID PITTING | RAY WIDTH | RAY HEIGHT | CROSSFIELD PITTING | RESIN TRACHEIDS |
|---|---|---|---|---|---|---|---|
| *Dadoxylon pseudoparenchymatosum* | Gothan (1908) | Present | 1 – 2 | Uni-v.r.p. biseriate | 2 – 10 | 2 – 6 | Septa |
| " " | Seward (1919) | Distinct | 1 – 2 | Usually uniseriate | 2 – 10 | several | Cross-bars |
| " " | Kräusel (1924) | " | 1 – 2 | Narrow rays | 1 – 18 (1 – 10) | several | Resin plates |
| " *kerguelense* | Seward (1919) | " | 1 – 2 | – | – | 5 – 8 | – |
| " " | Edwards (1921) | " | 1 – 2 | Uniseriate | 1 – 11 | up to 9 | Resin plates |
| " *novae – zeelandii* | Stopes (1914) | " | 2 | " | 1 – 7 (3 – 4) | 5 – 6 | Abundant |
| " " | Seward (1919) | " | 2 | " | 3 – 4 | 5 – 6 | Present |
| " *kaiparaense* | Edwards (1926) | " | 1 – 2 (v.r. 3) | " | 1 – 8 (2 – 3) | 1 – 10 | Some |

Table 19. Species synonymous with *Dadoxylon pseudoparenchymatosum*

Edwards (1926) in descibing Dadoxylon kaiparaense suggested that it is the wood of a species of Araucaria itself and that it probably bore the foliage of Araucarites marshalli, which were leaf fragments found in association but not attached to the wood.

It is interesting to note that Barton (1964) has described several Tertiary floras from King George Island and that from Admiralen Peak contains shoot and bark impressions of Araucaria.

Comparisons: G.536.2. This wood compares superficially with Dadoxylon amraparense, Dadoxylon australe, Dadoxylon mandroense and Dadoxylon mecsekense, although in all cases the rays are taller (up to 15 cells high) and a larger number of pits occur in the cross-fields.

The closest comparison is with Dadoxylon mandroense although it differs in that the number of pits in the cross-field is greater (2 - 6 (3 - 4) pits in early wood and 4 - 12 pits in late wood) compared with a constant 1 - 4 pits and that it has an opposite as well as alternate pitting arrangement on the tracheids which is not found in G.536.2. Dadoxylon mandroense also lacks any resin tracheids although this is probably a factor of minor importance.

In view of the fact that the wood described under G.536.2 is well preserved and appears distinct from all other woods of the Dadoxylon type, it is proposed to call it a new species, Dadoxylon kellerensis and it is named after the Keller Peninsula locality.

Dadoxylon kellerensis sp. nov. Diagnosis:

Secondary wood with distinct growth rings, late wood zone 2 - 3 cells wide, tracheids measuring 6·0µm to 11·5µm radially and 7·5µm to 11·5µm tangentially; early wood zone 20 - 29 cells wide, tracheids measuring 30·0µm to 38·0µm radially and 22·0µm to 45·0µm tangentially.

Radial tracheid pitting bordered, 1 - 3 (commonly 3) seriate with alternate, contiguous and flattened or hexagonal pits, measuring 9·5µm by 11·0µm to 12·0µm by 15·0µm. Pit pore central, round to oval in shape measuring

7·0µm by 7·5µm to 8·3µm by 10·5µm in diameter.

Xylem rays homogenous, uniseriate, 1 - 11 cells high (commonly 4 - 5 cells) in which cell members are barrel shaped.

Pits in the cross-field 1 - 4, sometimes arranged in pairs, bordered, with central pores measuring 5·2µm by 5·2µm to 7·5µm by 5·6µm in pits measuring 6·6µm by 6·6µm to 10·0µm by 7·5µm in diameter.

Comparisons: G.536.4/6/8. This wood compares with Dadoxylon alpinum, Dadoxylon catuanense, Dadoxylon chevalieri and Dadoxylon sidugawaense.

The best comparison is with Dadoxylon chevalieri which has well marked growth rings, uniseriate bordered pitting on the tracheids, rays 2 - 12 (commonly 4 - 6) cells high and 3 - 6 pits in the cross-field. The main differences are that it never has biseriate tracheidal pitting and that it possesses too many pits in the cross-field.

It is thought that the wood described under G.536.4/6/8 is not sufficiently well preserved (there being an element of doubt concerning the number of cross-field pits) to warrant consideration as a possible new species.

This wood will be referred to as simply Dadoxylon sp. until better material is found to provide a more complete and accurate diagnosis.

## DISCUSSION

Three wood taxa have been recognized from the material collected from Keller Peninsula, King George Island as decribed in chapter three of this Thesis.

G.536.A and G.536.B

Dadoxylon pseudoparenchymatosum Gothan

G.536.2, G.536.3, G.536.4, G.536.6, G.536.7 and G.536.8

Dadoxylon kellerensis sp. nov.

Dadoxylon sp.

Gymnosperm wood (indeterminate)

G.536.9, G.536.13 and G.536.14

Gymnosperm wood (indeterminate)

All of the woods represent new records for the locality.

## COMPARISON WITH OTHER WOOD FLORAS

Dadoxylon pseudoparenchymatosum has been described from Seymour Island, Antarctica (the Type locality, Gothan, 1908, Seward, 1919); Kerguelen Island, South Indian Ocean (Seward, 1919, Edwards, 1921); South Patagonia, South America (Kräusel, 1924); New Zealand (Stopes, 1914, Seward, 1919, Edwards, 1926) [Kräusel (1925), cited in Florin (page 38, 1940) has also described this species from Argentina. = Krausel, 1924]

## AGE

Dadoxylon pseudoparenchymatosum from Seymour Island, South Patagonia and Kerguelen Island has been found in Tertiary (possibly early Tertiary) deposits, that from Chubut in Argentina was found in Oligocene deposits and specimens from New Zealand are slightly older and are Mid - Upper Cretaceous in age.

It is more likely that the woods from King George Island are contemporary with the Tertiary material of Seymour Island, South America and Kerguelen Island than with the more remote Cretaceous material of New Zealand.

This Tertiary age for the woods is indirectly supported by the fact that several floras of this age have been described from different localities on King George Island (Barton, 1964 and Orlando, 1964) and included in one of the floras were Araucarian remains.

No plant remains (apart from wood) have yet been found at Keller Peninsula.

## CLIMATIC INDICATIONS

All of the well preserved woods reveal prominent growth rings with a very sparse development of late wood, only 2 - 3 layers thick.

This suggests not only a seasonal change but a sharply divided boundary between the favourable and unfavourable growing conditions and this is indicative of a cold temperate climate.

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## Notes

Krausel,R (1925) was cited by Florin (page 38, 1940) but not included in his bibliography and it has been impossible to locate this reference. Davies (in press 1 and 2) was brought to my attention by M. R. A. Thomson (pers. comm.) but limited information on these references prevented their inclusion in the bibliography.

PLATE 15

Plate 15.56 Wood block (A). 7cm. long x 5cm. wide.

Specimen Number G.536.A

Plate 15.57 Wood (A). Scanning electron micrograph of fractured surface. Magnification approximately X 500. Stub d.

Specimen Number G.536.A

Plate 15.58 Wood block ( B ). 5·6cm. long x 4·0cm. wide.

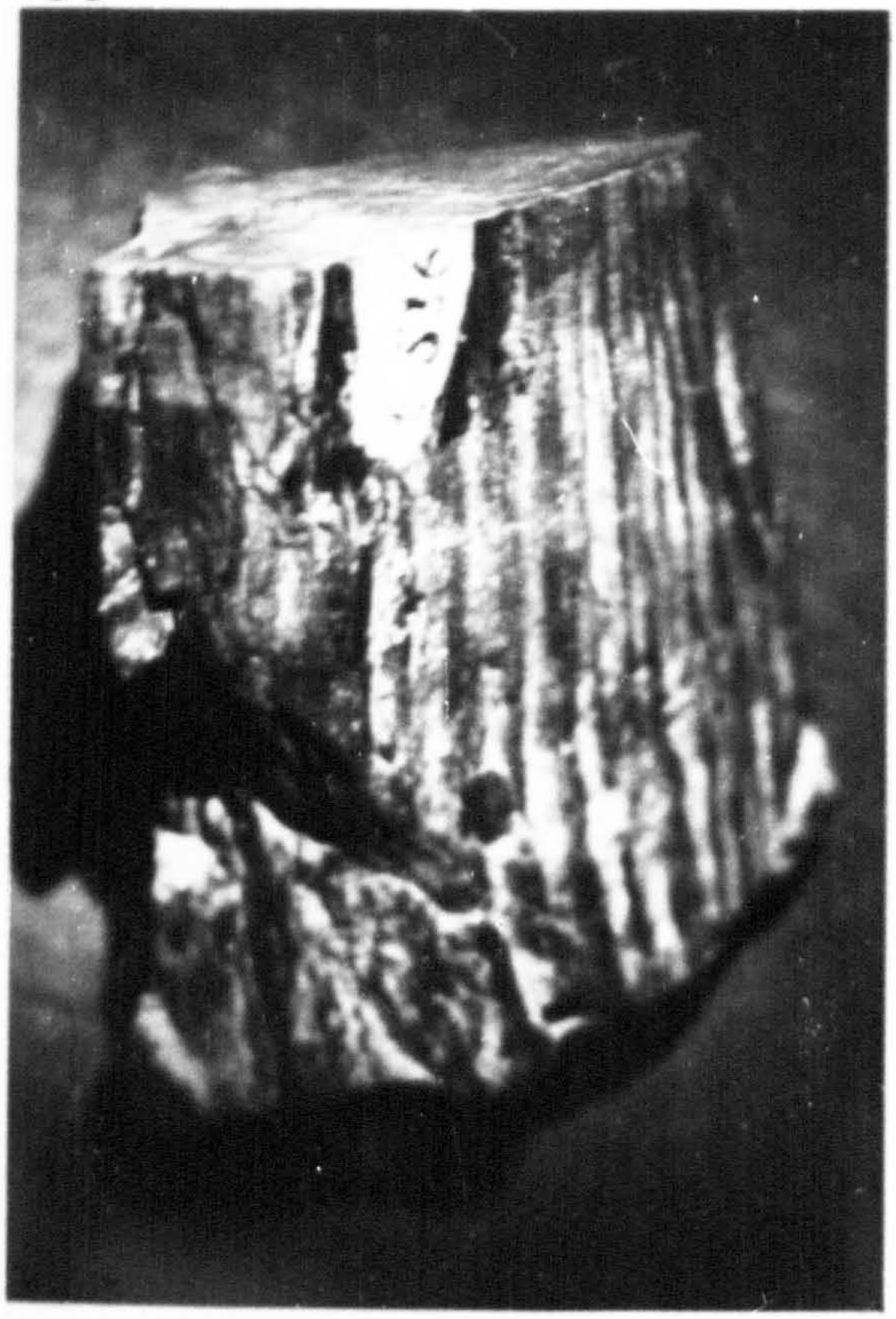
Specimen Number G.536.B

Plate 15.59 Wood ( B ). Transverse section. Magnification approximately X 25.

Slide Number 1.

Specimen Number G.536.B

56

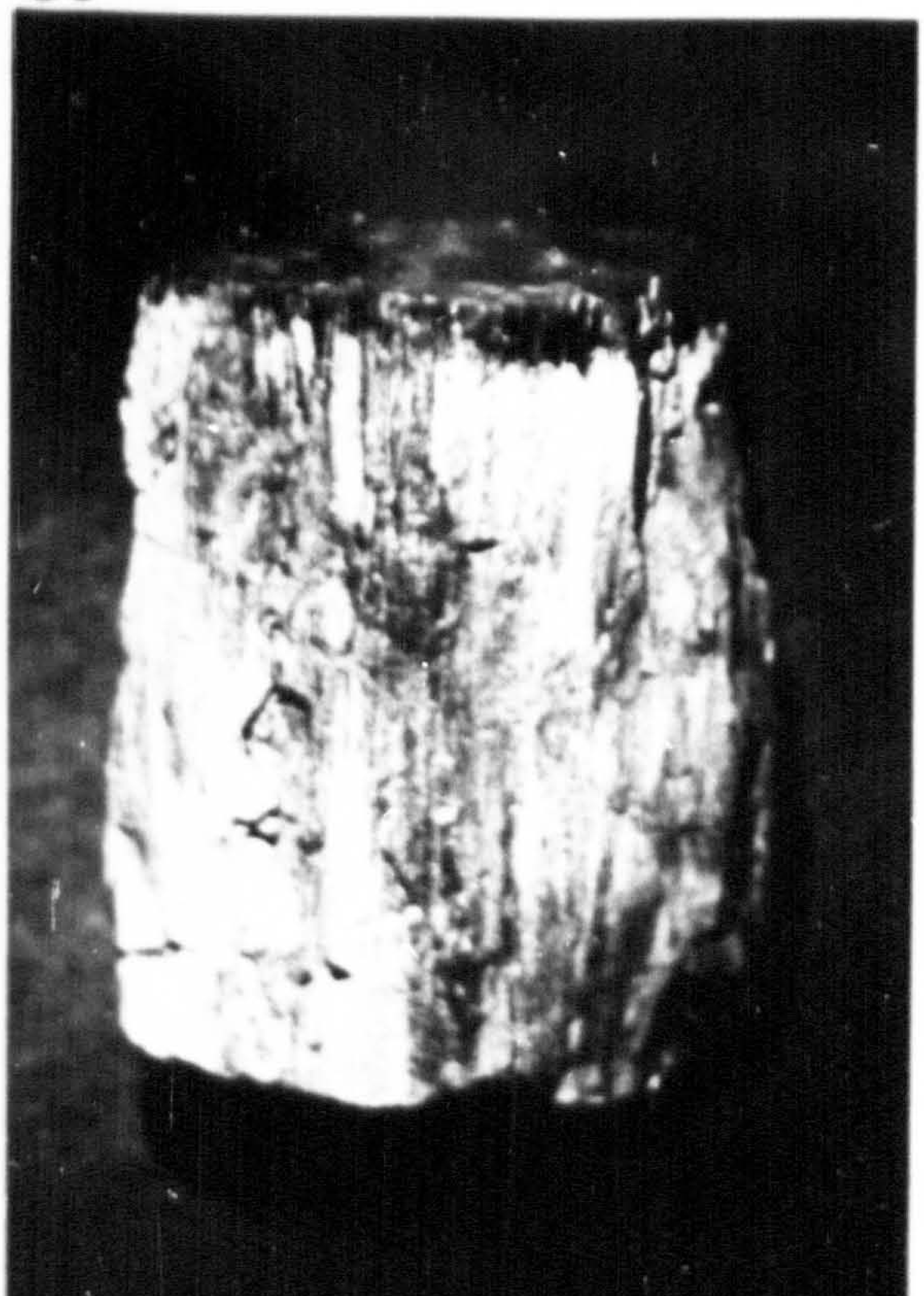


cm.

57

0·1mm.

58



cm.

59

mm.

PLATE 16

Plate 16.60 Wood (B). Transverse section. Magnification approximately X 100.

Slide Number 1.

Specimen Number G.536.B

Plate 16.61 Wood (B). Tangential longitudinal section.

Magnification approximately X 100.

Slide Number 4.

Specimen Number G.536.B

Plate 16.62 Wood (B) Radial longitudinal section.

Magnification approximately X 100.

Slide Number 2.

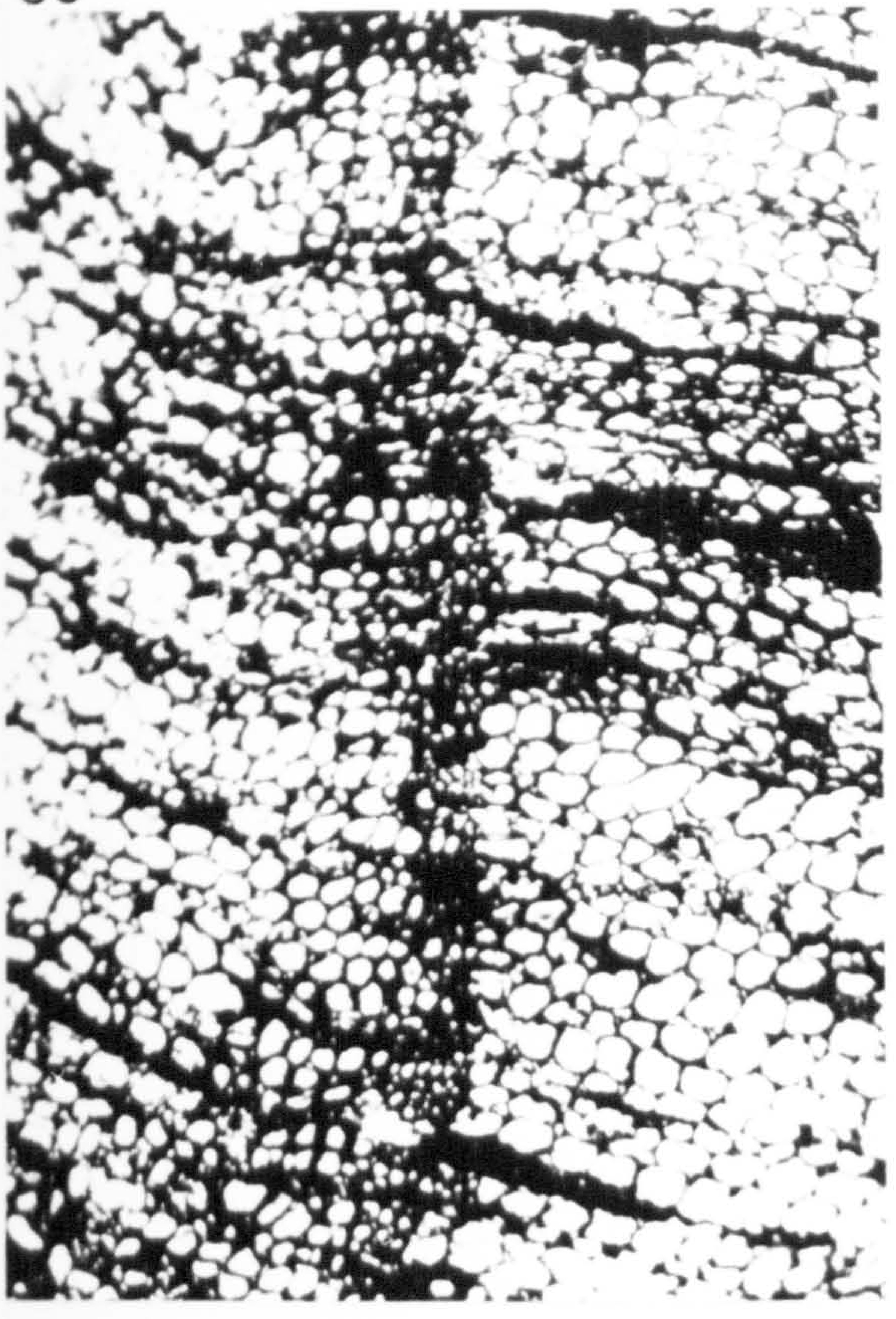
Specimen Number G.536.B

Plate 16.63 Wood (B). Scanning electron micrograph of fractured surface revealing tracheid and rays.

Magnification approximately X 170. Stub f.

Specimen Number G.536.B

60



0·5mm.

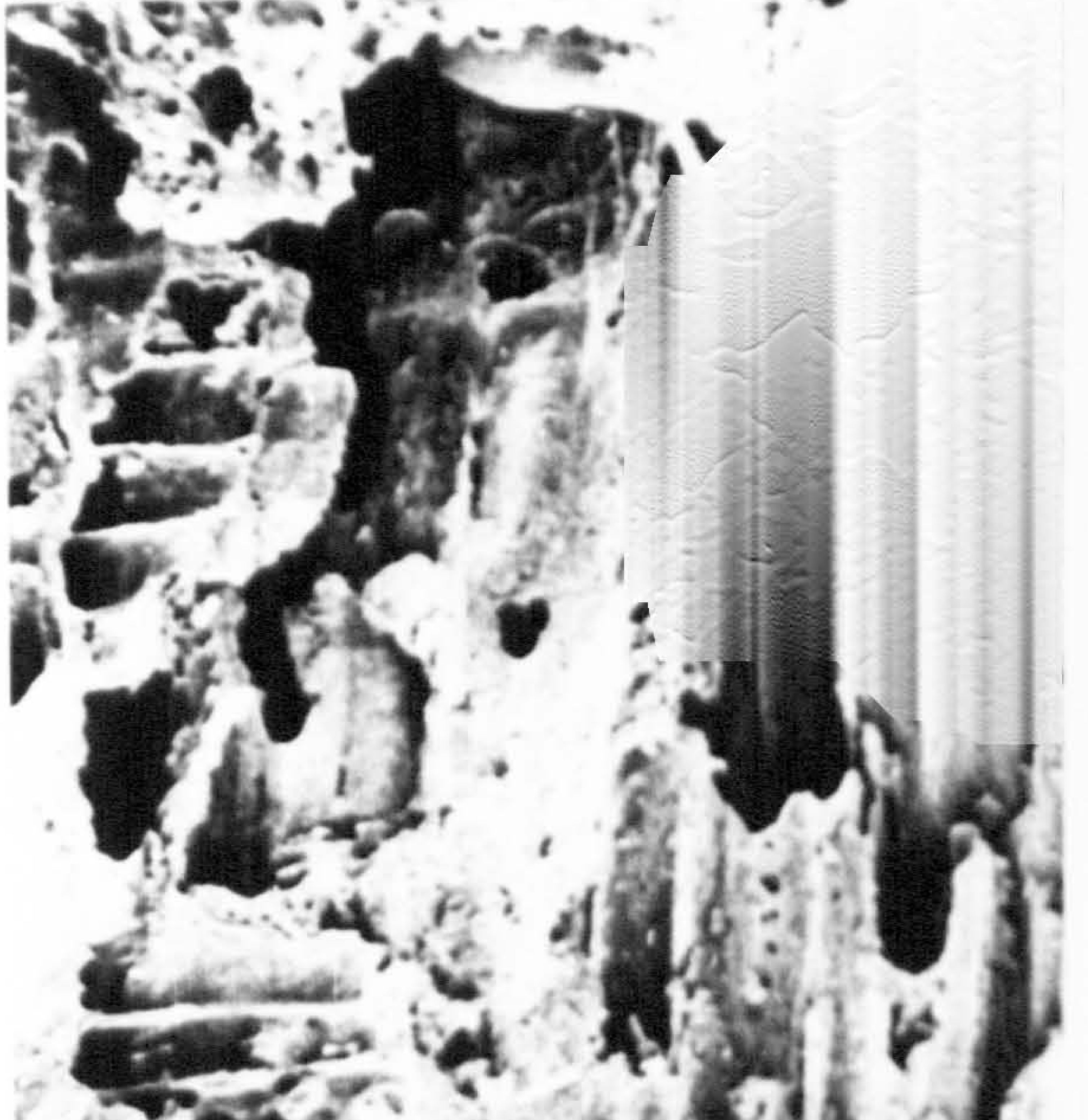
61

0·5mm.

62

0·5mm.

63



0·25mm.

PLATE 17

Plate 17.64 Wood ( B ). Scanning electron micrograph of fractured surface revealing ray detail. Magnification approximately X 925. Stub f. Specimen Number G.536.B

Plate 17.65 Wood ( B ). Scanning electron micrograph of fractured surface revealing details of tracheid pitting. Magnification approximately X 1,150. Stub f.

Specimen Number G.536. B

Plate 17.66 Wood Block 2. 8cm. long x 3·7cm. wide.

Specimen Number G.536.2

Plate 17.67 Wood 2. Transverse section. Magnification approximately X 25.

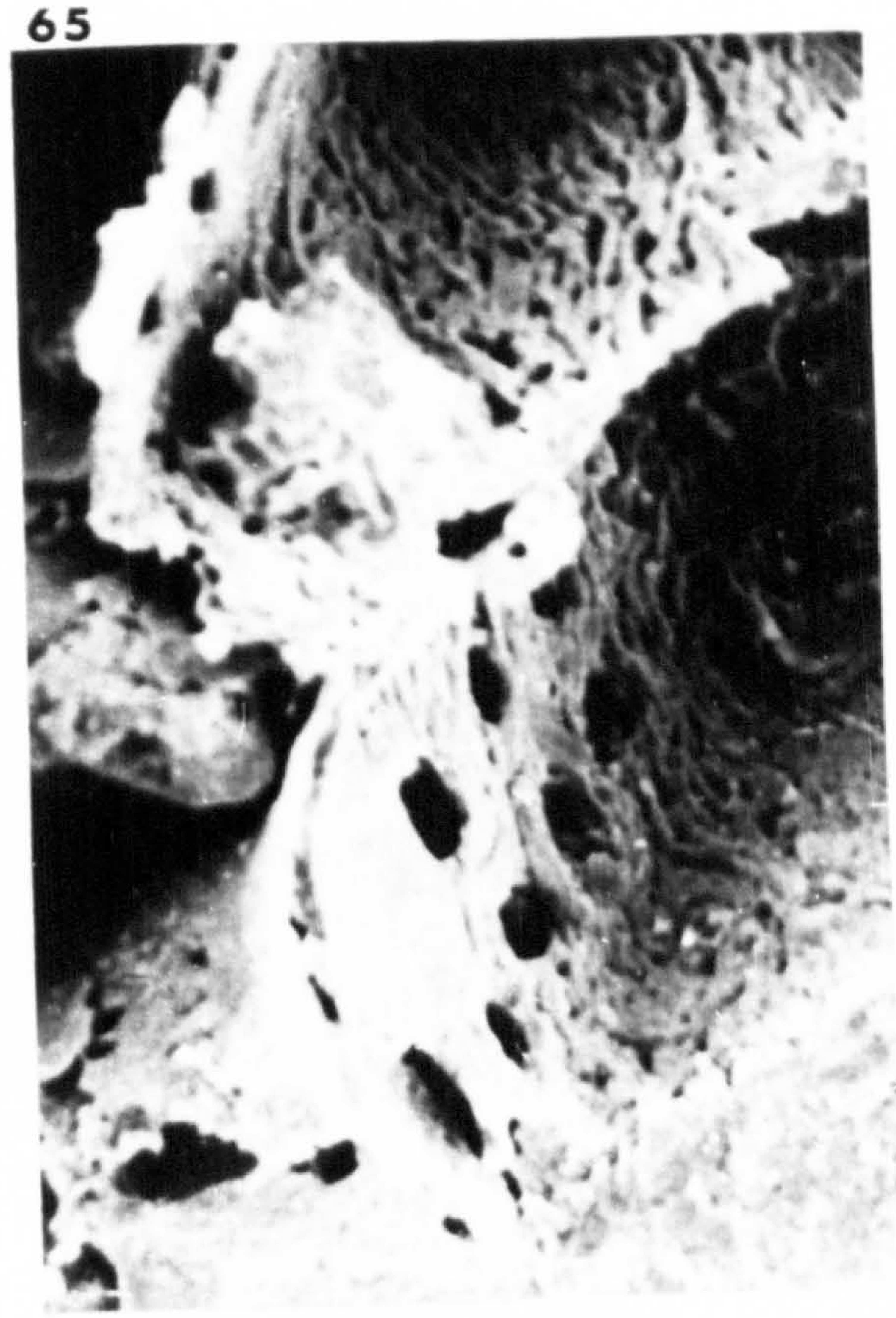
Slide Number 5.

Specimen Number G.536.2

64

0·05mm.

65



0·05mm.

66

cm.

67

mm.

PLATE 18

Plate 18.68 Wood 2. Transverse section. Magnification approximately X 100.

Slide Number 5.

Specimen Number G.536.2

Plate 18.69. Wood 2. Tangential longitudinal section. Magnification approximately X 100.

Slide Number 7.

Specimen Number G.536.2

Plate 18.70 Wood 2. Radial longitudinal section. Magnification approximately X 100.

Slide Number 6.

Specimen Number G.536.2

Plate 18.71 Wood block 3 (compressed axis on surface of rock). 5·2cm long x 1·7cm. wide and up to 2mm. thick.

Specimen Number G.536.3

68

0·5mm.

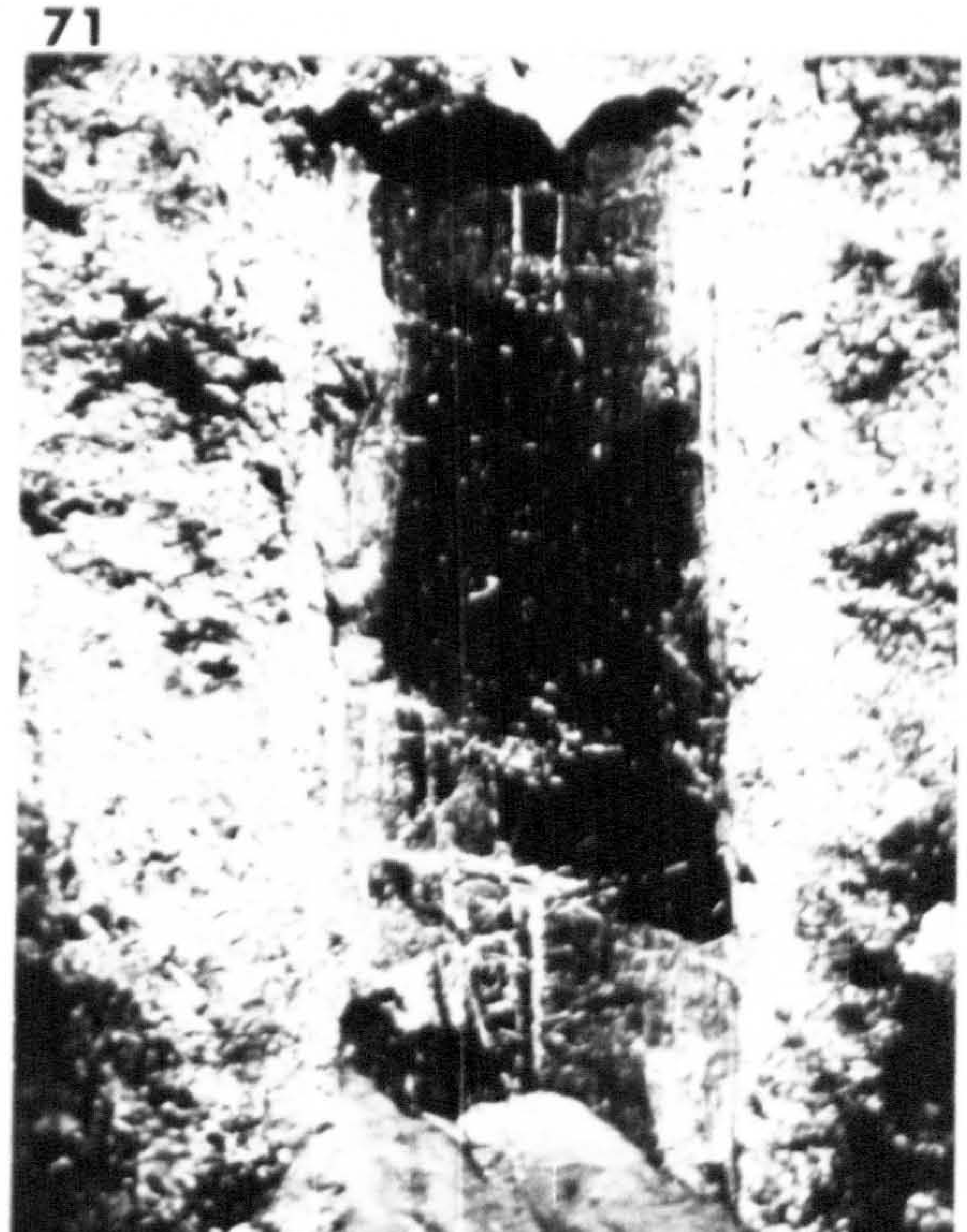
69

0·5mm.

70

0·5mm.

71



m.

PLATE 19

Plate 19.72 Wood block 6. 4·7cm. long x 1.6cm. wide.

Specimen Number G.536.6

Plate 19.73 Wood 6. Transverse section. Magnification approximately X 25.

Slide Number 10.

Specimen Number G.536.6

Plate 19.74 Wood 6. Transverse section. Magnification approximately X 100.

Slide Number 10.

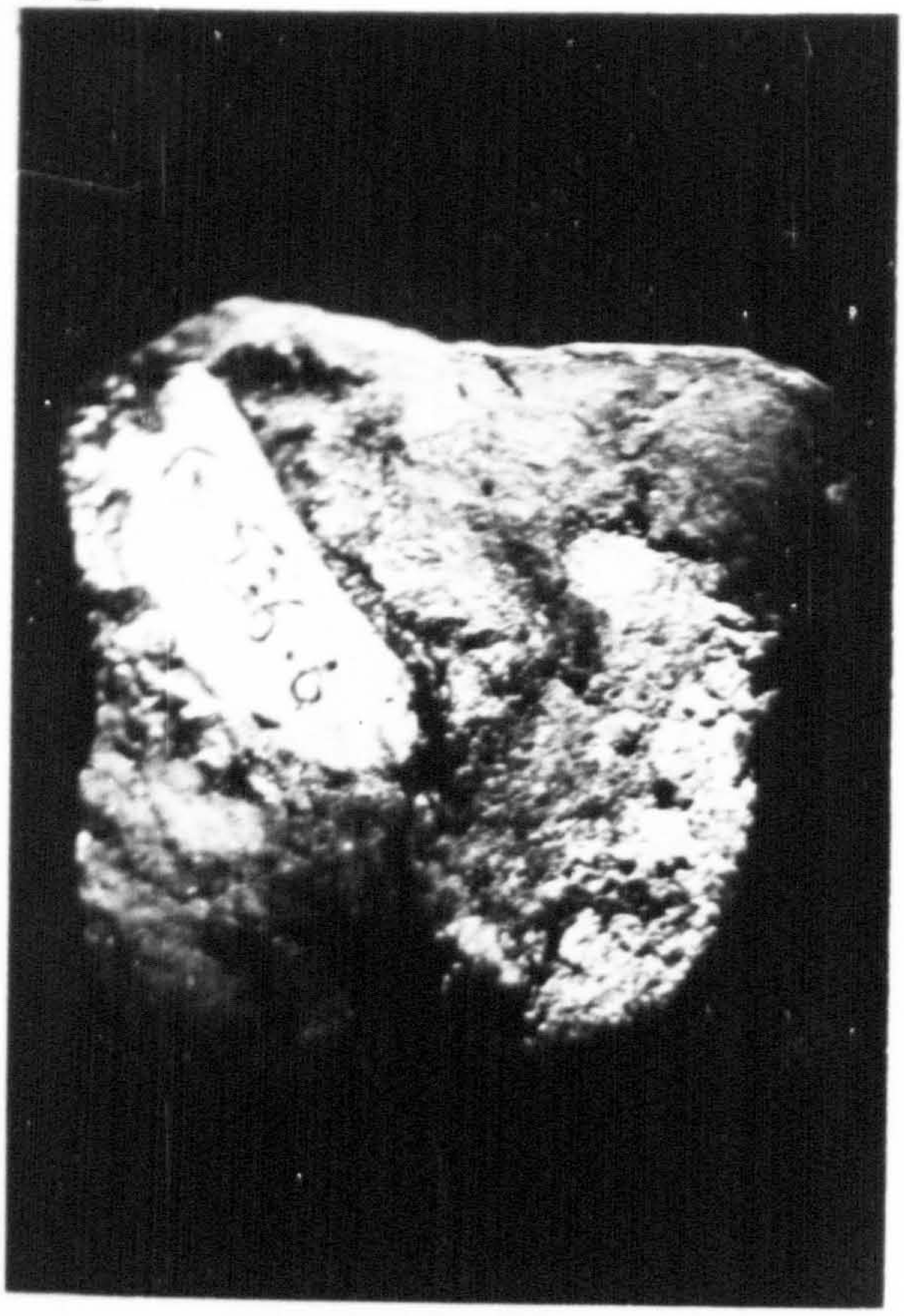
Specimen Number G.536.6

Plate 19.75 Wood 6. Tangential longitudinal section. Magnification approximately X 100.

Slide Number 9.

Specimen Number G.536.6

72

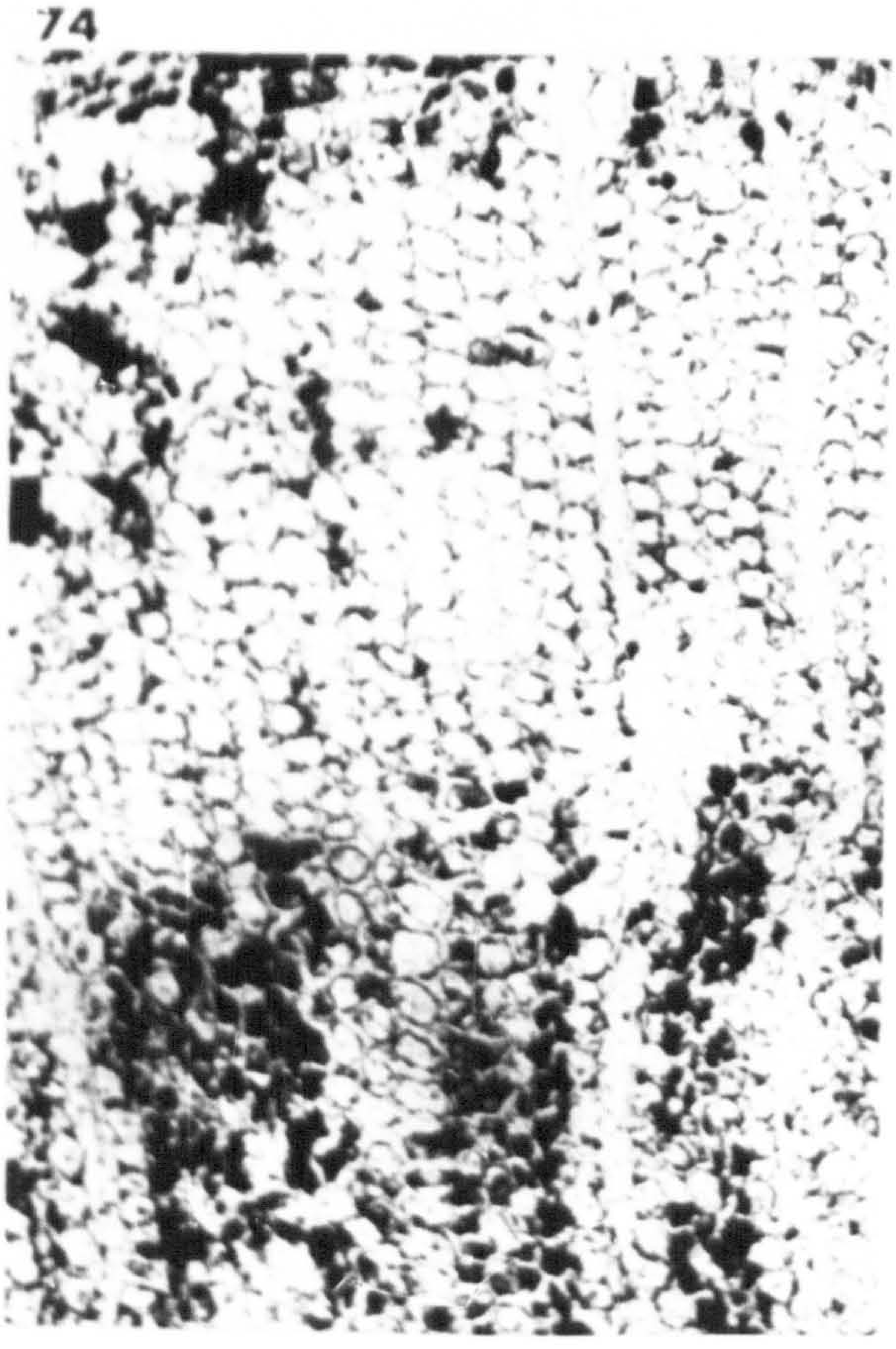


cm.

73

mm.

74



0·5mm.

75

0·5mm.

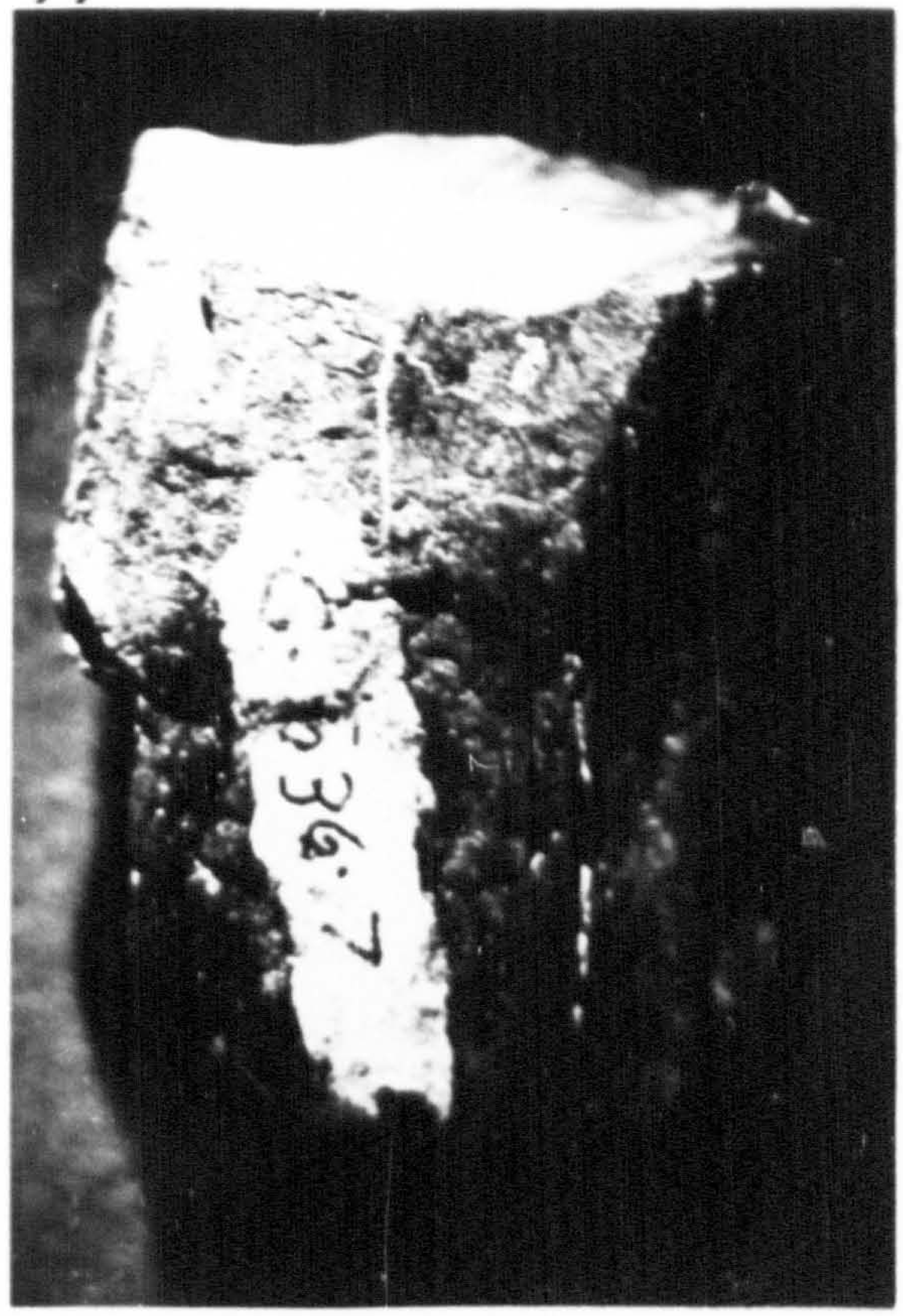
PLATE 20

| | | |
|---|---|---|
| Plate 20.76 | Wood 6. Radial longitudinal section.<br>Magnification approximately X 100.<br>Slide Number 11.<br>Specimen Number G.536.6 |
| Plate 20.77. | Wood block 7. 4·1cm. long x 3·0cm. wide.<br>Specimen Number G.536.7 |
| Plate 20.78 | Wood 7. Transverse section.<br>Magnification approximately X 100.<br>Slide Number 14.<br>Specimen Number G.536.7 |
| Plate 20.79 | Wood blocks 4 and 8 (part and counterpart).<br>Block 4, 7·0cm. long x 4.7cm. wide.<br>Block 8, 4·9cm. long x 4·75cm. wide.<br>Specimen Numbers G.536.4 and G.536.8. |

76

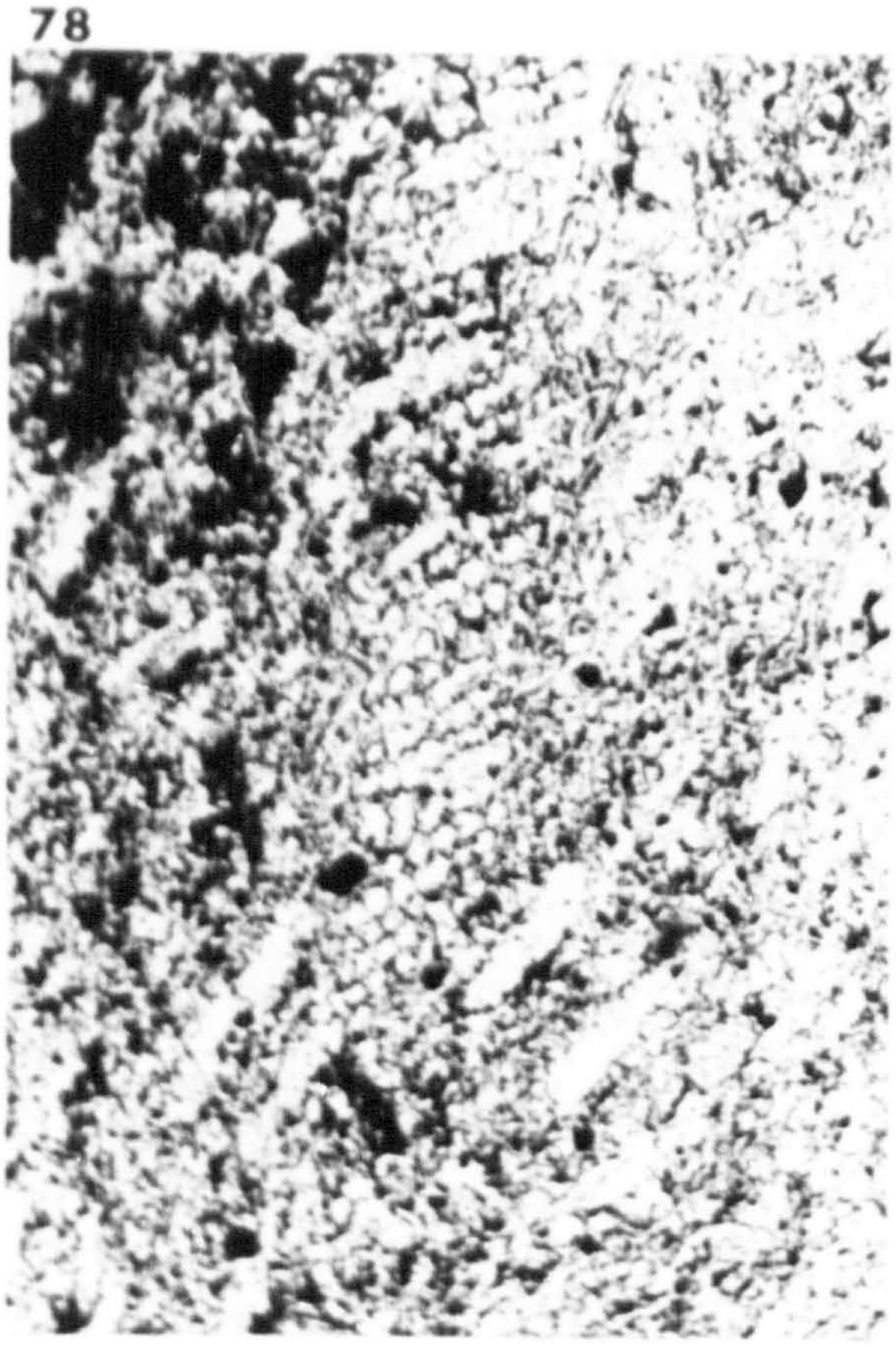
0·5mm.

77



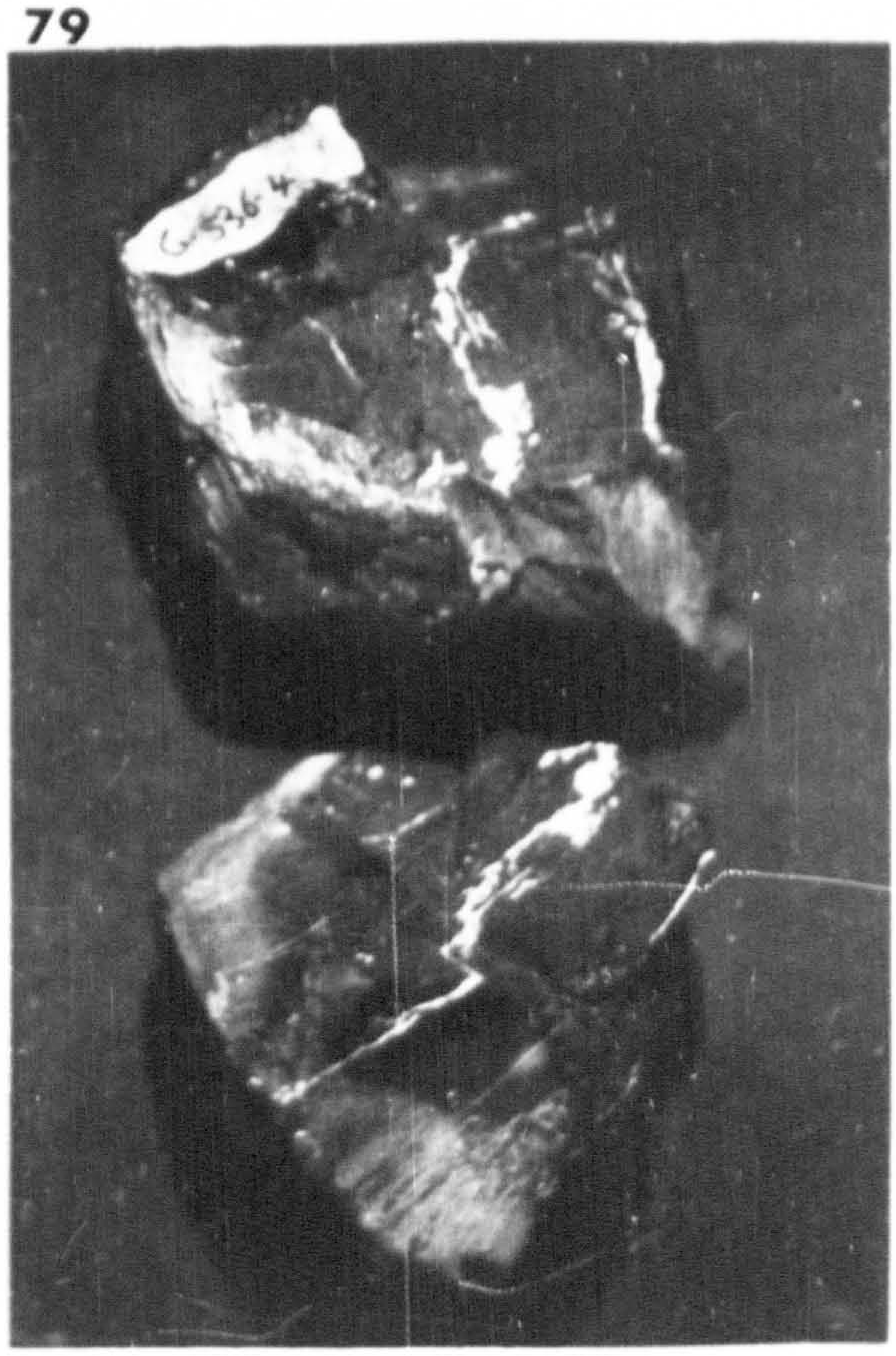
cm.

78



0·5mm.

79



cm.

PLATE 21

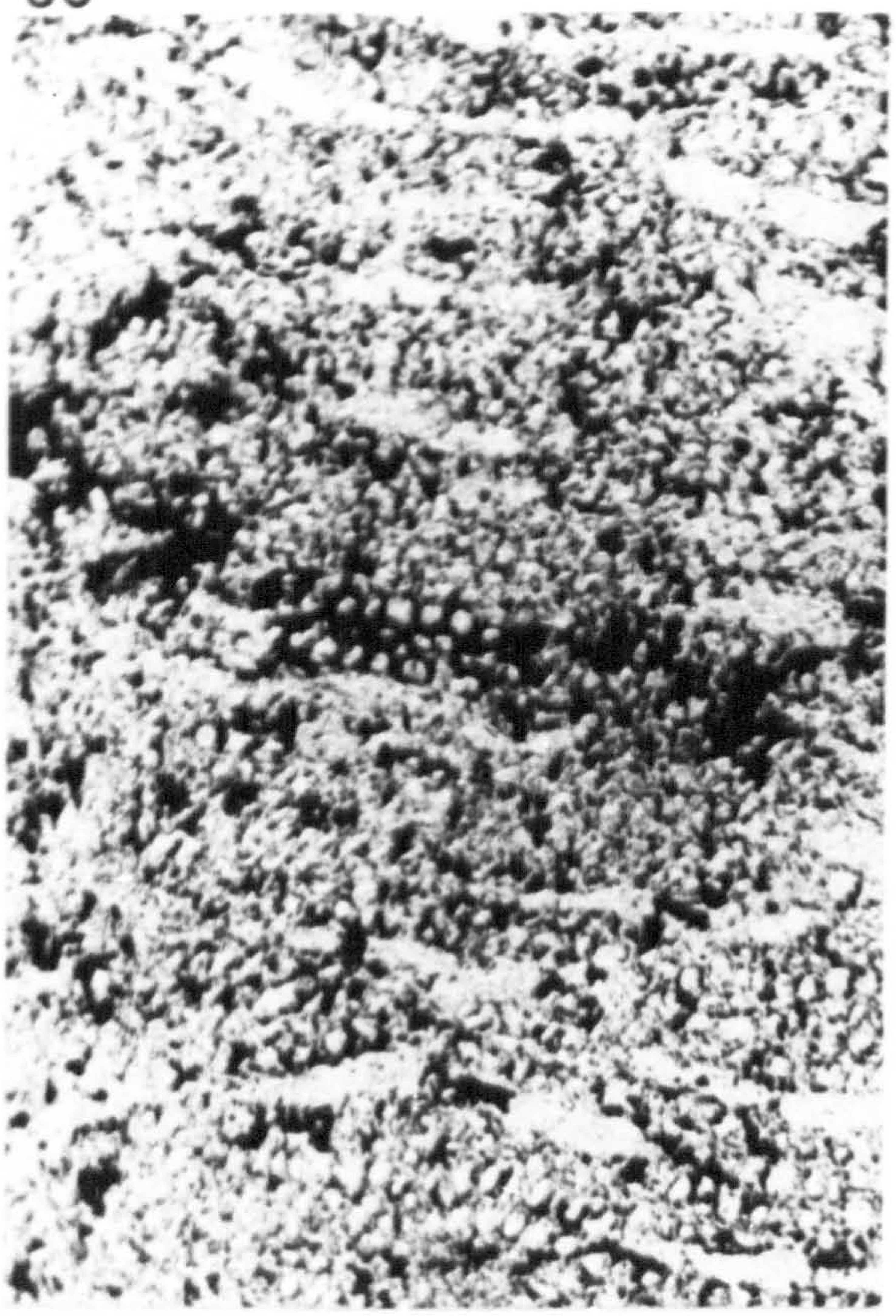
Plate 21.80 Wood 8. Transverse section. Magnification approximately X 100.
Slide Number 15.
Specimen Number G.536.8

Plate 21.81 Wood 8. Tangential longitudinal section.
Magnification approximately X 100.
Slide Number 17.
Specimen Number G.536.8

Plate 21.82 Wood 8. Radial longitudinal section.
Magnification approximately X 100.
Slide Number 16.
Specimen Number G.536.8

Plate 21.83 Wood block 9. 8·7cm. long x 6·8cm. wide.
Specimen Number G.536.9

80



0·5mm.

81

0·5mm.

82

0·5mm.

83

cm.

PLATE 22

Plate 22.84 Wood block 13. 9·0cm. long x 9·5 cm. wide.

Specimen Number G.536.13

Plate 22.85 Wood 13. Scanning electron micrograph of fractured surface revealing tracheids.

Magnification approximately X 415.

Stub a.

Specimen Number G.536.13

Plate 22.86 Wood 13. Scanning electron micrograph. Detail of tracheid pitting seen in plate 22.85.

Magnification approximately X 2,700.

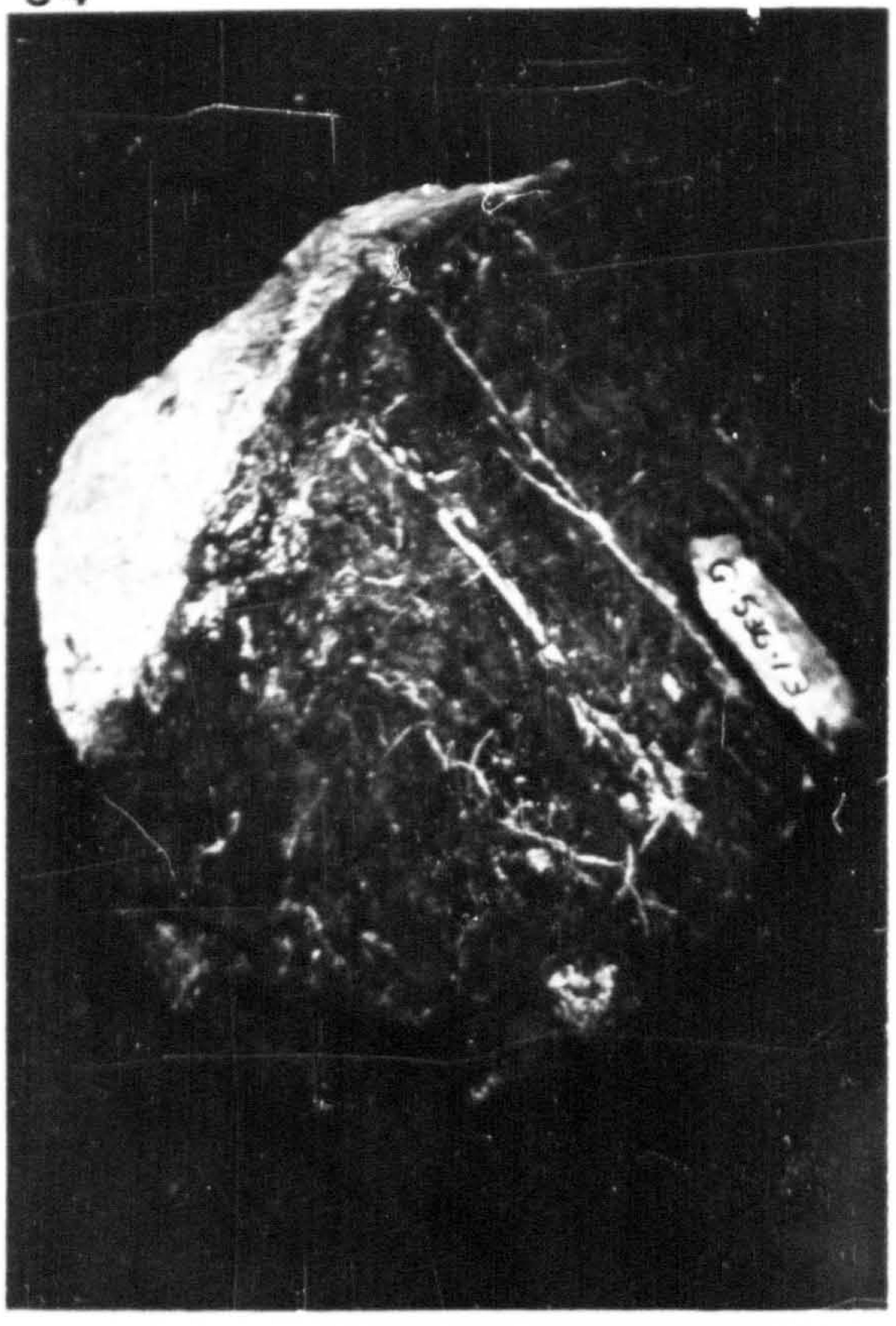
Stub a.

Specimen Number G.536.13

Plate 22.87 Wood block 14. 10cm. long x 10·5cm. wide and up to 3·1cm. thick.

Specimen Number G. 536.14

84



cm.

85

0·1mm.

86

0·01mm.

87

cm.

# APPENDICES

## APPENDIX 1

### CATALOGUE OF MATERIAL FROM THE THERON MOUNTAINS

Z.487.16 *Glossopteris communis*, *Glossopteris indica* (x2), cf. *Glossopteris* spp., *Glossopteris* sp. (cf. *G. indica*) and possible fructification.

Z.487.17 *Glossopteris communis*, *Glossopteris indica*, *Glossopteris* sp.

Z.487.18 *Glossopteris indica*.

Z.487.19 *Glossopteris communis*, *Glossopteris indica*, cf. *Gangamopteris angustifolia*.

Z.487.20 *Glossopteris indica*, *Glossopteris browniana*, *Glossopteris* sp.

Z.487.21 *Glossopteris communis*, *Glossopteris indica*, *Glossopteris* cf. *communis/indica*.

Z.487.22 *Glossopteris communis*, *Glossopteris indica*.

Z.487.23 Axis (indeterminate).

Z.487.24 *Glossopteris communis*, axes (x2, indeterminate).

Z.487.25 *Glossopteris communis*, *Glossopteris indica*, *Glossopteris* spp., cf. *Gangamopteris* sp.

Z.487.26 *Glossopteris indica*, fragmented axis (indeterminate).

Z.487.27 *Glossopteris indica*.

Z.487.28 *Glossopteris* spp., axis (indeterminate).

Z.487.29 *Glossopteris indica*, *Glossopteris stricta*, *Glossopteris* cf. *Indica/browniana*, cf. *Gangamopteris* sp.

Z.487.30 *Glossopteris indica* (with long petiole), axis (indeterminate).

Z.487.31 *Glossopteris communis*, *Glossopteris indica*.

Z.487.32 *Glossopteris communis*, *Glossopteris* cf. *indica*.

Z.487.33 *Glossopteris communis*.

Z.487.34 *Glossopteris communis*, *Glossopteris indica*, *Glossopteris stricta*, cf. *Gangamopteris* sp. (basal fragment).

Z.487.35 Glossopteris communis (x2), Glossopteris indica, axis (indet.).

Z.487.36 Glossopteris communis, Glossopteris indica.

Z.487.37 Glossopteris communis, Glossopteris browniana, Glossopteris spp.

Z.487.38 Axes (x2, indeterminate).

Z.487.39 Glossopteris indica.

Z.487.40 Glossopteris indica, Glossopteris browniana (small fragment).

Z,487.41 Glossopteris communis, axis (indeterminate).

Z.487.42 Glossopteris communis, axes (x2, indeterminate), seeds ?, (cf. Samaropsis sp.).

Z.487.43 Glossopteris communis, Glossopteris indica, Glossopteris browniana, Glossopteris angustifolia.

Z.487.45 Glossopteris indica, Glossopteris conspicua (small fragment).

Z.487.46 Glossopteris indica (x2), Glossopteris browniana.

Z.487.47 Glossopteris indica, seeds ? (cf. Samaropsis sp.).

Z.487.48 Glossopteris communis, Glossopteris indica, Glossopteris browniana.

Z.487.49 Glossopteris communis, Glossopteris browniana, Glossopteris cf. communis, cf. Gangamopteris sp. (with apical notch).

Z.487.50 Glossopteris communis, Glossopteris indica.

Z.487.51 Glossopteris communis (x3), Glossopteris indica (x2), Glossopteris cf. indica/browniana, Glossopteris sp.

Z.487.52 Glossopteris communis, Glossopteris indica, axes (x2, indet.).

Z.487.53 Glossopteris communis, Glossopteris indica, Glossopteris browniana, Glossopteris sp., axis (indeterminate).

Z.487.55 Vertebraria indica (type a and b).

( Specimens Z.487.44 and Z.487.54 were absent. Specimens Z.487.19/30 are counterparts, as are 29/34, 29/39, 31/33, 35/40 and 36/46).

Z.508.2 Glossopteris communis, Glossopteris indica, Glossopteris browniana, Glossopteris angustifolia, Glossopteris sp., Z.508.2 cont. Glossopteris cf. browniana/conspicua, cf. Gangamopteris sp., scale leaf.

Z.508.3 Axis (with leaf, scale or seed scars ?).

Z.508.6 Glossopteris indica, Glossopteris angustifolia, Glossopteris spp., Vertebraria indica.

Z.508.7 Glossopteris communis, Glossopteris indica, Glossopteris browniana, Glossopteris spp.

Z.508.9 Glossopteris conspicua, carbonaceous fragment (indeterminate).

( Specimens Z.508.4, Z.508.5 and Z.508.8 were absent ).

Z.499.8 Paracalamites australis.

Z.472.14 Glossopteris conspicua, Glossopteris cf. communis/indica, Glossopteris cf. indica/browniana, Foraminifera spp.

Z.471.3 Glossopteris cf. browniana/conspicua, Glossopteris sp.

Z.498.20 (i) Glossopteris conspicua (x2), Glossopteris sp.

(ii) Glossopteris cf. conspicua, Glossopteris cf. angustifolia, Vertebraria indica, axis (indeterminate).

(iii) Glossopteris conspicua (x2), Vertebraria indica, axis (indet).

(iv) Glossopteris conspicua (x2), Glossopteris angustifolia, Glossopteris indica, Glossopteris sp., Vertebraria indica.

( Specimens Z.498.20 (i) and Z.498.20 (iii) are counterparts ).

Z.475.3B Organic remains ?.

## APPENDIX 2

### CATALOGUE OF MATERIAL FROM LIVINGSTON ISLAND

P.224.2 Branching axis (indeterminate).

P.224.3 Branching axis (indeterminate).

P.224.4 Branching axis (indeterminate).

P.224.5 Fragment (indeterminate).

P.224.6 Axes, including branching axis (indeterminate).

P.224.7 Branching axis, possible leaf (indeterminate).

P.224.8 Fragments, including leaf remains (indeterminate).

P.224.9 cf. Dicroidium (Xylopteris) spinifolia,
fine branching axis and fragments (indeterminate).

P.224.10 Axis and other fragments (indeterminate).

P.224.11 Dichotomising axes (all indeterminate).

P.224.12 Very fine axis and other fragments (all indeterminate).

P.224.13 Filamentous axes (indeterminate).

P.224.14 Axis and leaf/axis fragments (indeterminate).

P.224.15 Axis fragments (indeterminate).

P.224.16a Possible leaf with midrib , no venation (indeterminate).

P.224.16b Large numbers of small axes (cf. Equisetites sp.).

P.224.17 Branching axis and assorted axes and leaves (indeterminate).

P.224.18 cf. Asterotheca crassa, Pagiophyllum sp., Doratophyllum
(Taeniopteris) tenison-woodsi.

P.224.19 Pagiophyllum sp. (x14+).

P.224.20 Pagiophyllum sp., dichotomising axis (indeterminate).

P.224.21 Thallites spp. (type a and b), Equisetites sp., Hexagonocaulon
minutum gen. et sp. nov.

P.224.22 Pagiophyllum sp. (x10).

P.224.23 Branched axis and assorted fragments (indeterminate).

P.224.24 Large axis (indeterminate).

P.224.25 Equisetites sp., cf. Asterotheca crassa, Hexagonocaulon minutum gen. et sp. nov.

P.224.26 Equisetites sp., Dicroidium (Xylopteris) cf. spinifolia.

P.224.27 Equisetites sp., cf. Asterotheca crassa, cf. Dicroidium (Xylopteris) sp., Ginkgoites sp., Hexagonocaulon minutum gen. et sp. nov., large axis (indeterminate).

P.224.28 Pagiophyllum sp. (x12)

P.224.29 Equisetites sp., Hexagonocaulon minutum gen. et sp. nov.

P.224.30 Equisetites sp.

P.224.31 Pagiophyllum sp. and remains of possible cone.

P.224.32 Equisetites sp, cf, Asterotheca crassa, Hexagonocaulon minutum gen. et sp. nov., branched axis (indeterminate).

P.224.33 Pagiophyllum sp. (x2).

P.224.34 Pagiophyllum sp. (x2), assorted fragments.

P.224.35 Pagiophyllum sp. (x3).

P.224.36 Doratophyllum (Taeniopteris) tenison-woodsi (x4).

P.244.37 Dicroidium (Xylopteris) cf. spinifolia and assorted fragments.

P.224.38 Dicroidium cf. lancifolium (x3).

P.224.39 Branching axis (indeterminate).

P.224.40 cf, Asterotheca crassa (x2).

P.224.41 Pagiophyllum sp.

P.224.42 Pagiophyllum sp. and possible cone.

P.224.43 Pagiophyllum sp.

P.224.44 Leaf fragment (indeterminate).

P.224.45 Equisetites sp., axis with fine ribbing (indeterminate).

P.224.46 cf. Asterotheca crassa.

P.224.47 Pagiophyllum sp., axis (indeterminate).

P.224.48 cf. Asterotheca crassa, Ginkgoites sp., Hexagonocaulon minutum gen. et sp. nov., branching axes (indeterminate).

P.224.49 Pagiophyllum sp.

P.224.50 Pagiophyllum sp.

P.224.51 Pagiophyllum sp.

P.224.52 Pagiophyllum sp.

P.224.53 Pagiophyllum sp.

P.224.54 Leafy shoot (indeterminate).

P.224.55 cf. Asterotheca crassa, Pagiophyllum sp.

P.426.4 Equisetites sp. (many), cf. Asterotheca crassa, leaves (possibly cf. Phoenicopsis/Ginkgoites type).

P.426.5 Equisetites sp. (many), Pterophyllum dentatum sp. nov.

P.426.6 Equisetites sp. (many), Pterophyllum dentatum sp. nov.

P.426.7 Leaf impression (indeterminate).

P.426.8 Leaf impression (indeterminate).

P.426.9 Pterophyllum dentatum sp. nov.

P.426.10 Leaf fragment (cf. Dipteridaceae).

P.426.11 Neocalamites sp. (x2), leaf remains (cf. Phoenicopsis/Sphenobaiera type).

P.426.12 Equisetites sp. (many).

(Specimen P.426.4/13 are counterparts, as are 6/9 and 7/8.)

## APPENDIX 3

### CATALOGUE OF MATERIAL FROM KING GEORGE ISLAND

G.536.A Wood block with growth rings and thickly ribbed outer surface.

G.536.B Wood block with growth rings and fine ribbing visible on the weathered surface.

G.536.2 Wood block with growth rings.

G.536.3 Compressed axis on surface of rock, with fine striations visible on the weathered exterior.

G.536.4 Wood block with growth rings preserved in localized patches.

G.536.6 Wood block with very little discernable surface detail.

G.536.7 Wood block with no exterior detail.

G.536.8 Wood block with well preserved growth rings.

G.536.9 Wood block with possible growth rings and fine ribbing detail visible on the weathered surface.

G.536.13 Wood block with possible growth rings and central hole.

G.536.14 Large wood block with possible growth rings and a thickly ribbed outer surface (as seen in G.536.A).