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PODOZAMITES AND ASSOCIATED CONES AND SCALES FROM THE UPPER TRIASSIC MOLTENO FORMATION, KAROO BASIN, SOUTH AFRICA

by

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ABSTRACT

The leaves *Podozamites elongatus* (Morris) Feistmantel from 24 localities, the cones *Telemachus elongatus* gen. et sp. nov. from nine localities and the scales *Dordrechtites elongatus* gen. et sp. nov. from seven localities are described from the Molteno Formation, Upper Triassic (Carnian), Karoo Basin, South Africa. On the basis of the close association of the leaves, cones and scales from certain localities it is probable that all three are derived from the same parent species belonging to the Coniferales.

CONTENTS

INTRODUCTION

Feistmantel (1889) published the first description of *Podozamites elongatus* (Morris) Feistmantel from the Molteno Formation. This type of leaf was reidentified as belonging to the genus *Phoenicopsis* by Seward (1903) and Du Toit (1927). In this study such leaves have been reassigned to *Podozamites*.

An extensive collecting programme from 42 localities in the Molteno Formation (Anderson, 1974) yielded *Podozamites* from 24 localities (table 1; fig. 1). This leaf genus is one of the most commonly preserved elements of the Molteno Flora and at certain horizons occurs virtually exclusively. At three of the nine localities from which the cone *Telemachus elongatus* gen. et sp. nov. and at two of the seven localities from which the scales *Dordrechtites elongatus* gen. et sp. nov. have been collected, these structures are found in close association with the leaves *Podozamites* (table 1, fig. 1). The suggestion is made that the leaves, cones and scales all derive from the same parent species.

In Gondwanaland *Podozamites* is widely distributed in the Upper Triassic (table 2; fig. 2) but is apparently absent earlier. The associated cones and scales, other than from the Molteno Formation, remain unrecorded from Gondwanaland. In Laurasia *Podozamites* occurs commonly in strata of Upper Triassic and Lower Jurassic age and is often found in association with certain cone genera (table 3).

EXPLANATION OF PLATES

The specimens are grouped according to taxa and by locality (indicated by locality code as listed in table 1). The specimens are catalogued both according to a collecting number (indicated by locality code and number) and a publication number (indicated by BPI (Pal) PB 315–383). These are given on the photographs by a pair of numbers: the upper being the collecting number and the lower the publication number.

SYSTEMATIC PALAEOBOTANY

Order: Coniferales

Genera: *Podozamites* Braun 1843
Telemachus gen. nov.
Dordrechtites gen. nov.

Species: *P. elongatus* (Morris 1845) Feistmantel 1889
T. elongatus gen. et sp. nov.
D. elongatus gen. et sp. nov.

PODOZAMITES ELONGATUS (Morris) Feistmantel

Synonymy

1845 *Zeugophyllites elongatus* Morris, Plate 6 (5, 5a)
1889 *Podozamites (Zeugophyllites) elongatus* (Morris) Feistmantel, Plate 2 (13), Plate 3 (3, 4, 7)
1903 *Phoenicopsis elongatus* (Morris) Seward, Plate 9 (1, 9, 10)
1961 *Desmiophyllum taeniatum* Lele, Plate 4 (45–47)

Holotype

Zeugophyllites elongatus Morris 1845, Plate 6 (5, 5a), Jerusalem basin, Tasmania.

Reference collection

Little Switzerland, 37 specimens of which two are illustrated (Plate 1 (4, 5)). The collection from this locality was selected in preference to others which have more complete leaves, as it yielded cuticular structure (Plate 9).

Description (based on reference collection)

Macro characters: Leaf simple, linear, no distinct petiole but lamina tapering over 10–20 mm towards proximal end, tip variable either tapering to an acute point or ending obtusely. Length of leaf 58(140)170 mm and width (central portion) 7(10)16 mm. Venation parallel (except at base and tip), on average 10 veins/10 mm, at base 2–4 veins which soon fork once or twice and which converge at tip.

Micro characters: Cuticle hypostomatic, upper cuticle thicker and without papillae, lower cuticle with strongly papillate epidermal cells. Epidermal cells 20–60 μm, square to rectangular in shape with straight fairly thick walls. Stomata variously orientated between vein areas, length 60–90 μm, usually with 5 subsidiary cells bearing distinct papillae which tend to form lappets over the opening, guard cells not clearly preserved.

Discussion

(a) Generic name

The assignment of these strap-shaped leaves to their correct genus is problematical. Such leaves from the Molteno have in the past been placed by Feistmantel (1889) in *Podozamites* and by Seward (1903) and Du Toit (1927) in *Phoenicopsis*. The main distinction between the two genera is that *Podozamites* leaves are attached helically to a stem and have been assigned to the Coniferophyta (Weber, 1968) while *Phoenicopsis* leaves occur in whorls along a stem and have been assigned to the Ginkgophyta (Tralau, 1968). The only mention of attachment from the Gondwana Triassic is by Tenison-Woods (1883, p. 110) who recorded specimens from the Ipswich Basin, Australia (no illustrations or sample and locality details available) as showing the same attachment as *Podozamites* from Europe. In spite of the extensive Molteno collections (table 1) no specimens showing attachment have been found, and other lines of evidence must therefore be considered.

The structure of the cuticle obtained from the Molteno specimens compares well with that described by Harris (1935) and Doludenko (1967) for *Podozamites* species, while it is unlike the cuticle structure as recorded by Tralau (1968) for genera placed by him in the Phoenicopsiaceae.

In Laurasia *Podozamites* frequently occurs in close association with the cone genera *Cycadocarpidium* and *Swedenborgia* and recently organic attachment was recorded between *Podozamites* and *Cycadocarpidium* by Stanislavsky (1976). The cones are similar to the Molteno cones here described as *Telemachus elongatus* gen. et sp. nov. which are also found in close association with the leaves in question. This circumstantial evidence points towards *Podozamites* rather than *Phoenicopsis*.

(b) Specific name

The choice of specific name is restricted to a consideration of species described from the Gondwana Triassic, it being beyond the scope of this study to review the numerous *Podozamites* species derived from other regions and periods.

(c) Illustrations

Plate 1 (1–8) — a few individual leaves show some of the variation in size and shape encountered at three localities.

Plate 1 (9) — detail of venation is shown on a slab from Matatiele II where the veins are particularly clearly preserved. On these leaves striations between the veins, termed interstitial veins by Harris (1926), are seen.

Plate 1 (10, 11), Plate 8 (1, 2) — show accumulations of leaves from four different localities.

Plates 6 and 7 — illustrate the close association encountered between leaves and fertile structures.

Plate 9 — photomicrographs of the upper and lower cuticle showing epidermal cells, stomata and papillae.

(d) Cuticle

Preparation. Great difficulty was experienced in obtaining cuticular preparations. Of the 24 Molteno localities at which *P. elongatus* occurs only two (Little Switzerland and Upper Umkomaas) yielded carbonaceous specimens. Little Switzerland has previously yielded good quality cuticle, for instance for *Dicroidium* (Anderson, 1976) and various Ginkgophyta genera, while at Upper Umkomaas cuticle preservation of corresponding genera has been poor. A total of 30 preparations was made from *P. elongatus* leaves, only six of which produced cuticular structure (Little Switzerland — two fair and three indistinct preparations; Upper Umkomaas — one indistinct preparation). Both Harris (1935) and

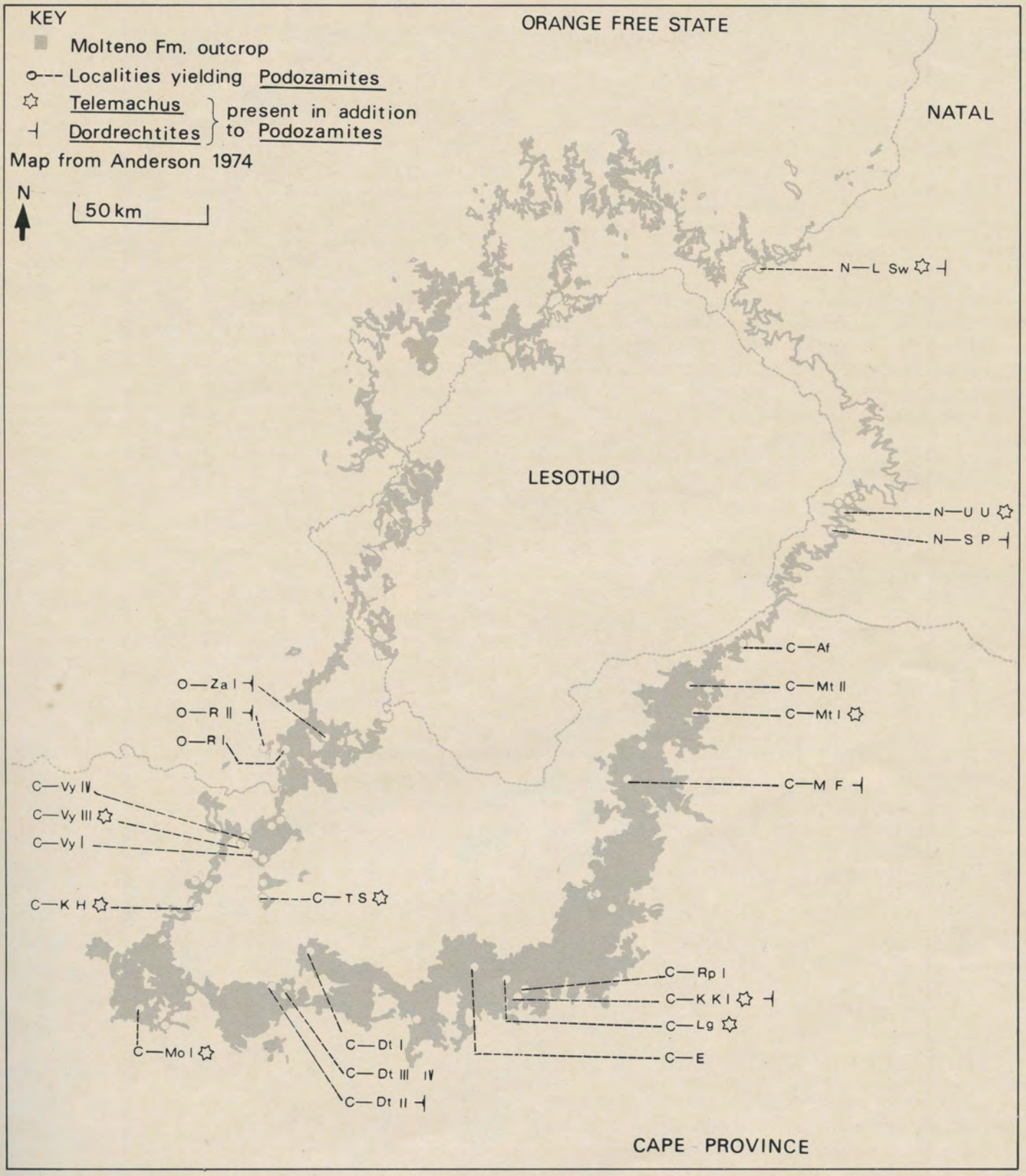

Figure 1. Distribution of *Podozamites, Telemachus, Dordrechtites* in the Molteno Formation.

Doludenko (1967), who succeeded in isolating the cuticle of *Podozamites*, noted that it was thin and difficult to prepare. Jones and De Jersey (1947) recorded that they were unable to isolate the cuticle from specimens occurring at Ipswich, Australia. The Molteno preservation is thus in accordance with that noted elsewhere to date.

Comparisons. The only cuticular studies published to date on *Podozamites* (of which the author is aware) are: a single species by Doludenko (1967) from the Upper Jurassic of the Bureya Basin, U.S.S.R; four species by Harris (1926, 1935) from the Rhaeto-Liassic of Greenland; and a single species by Florin (1953) from the Liassic of Sweden. The Little Switz-

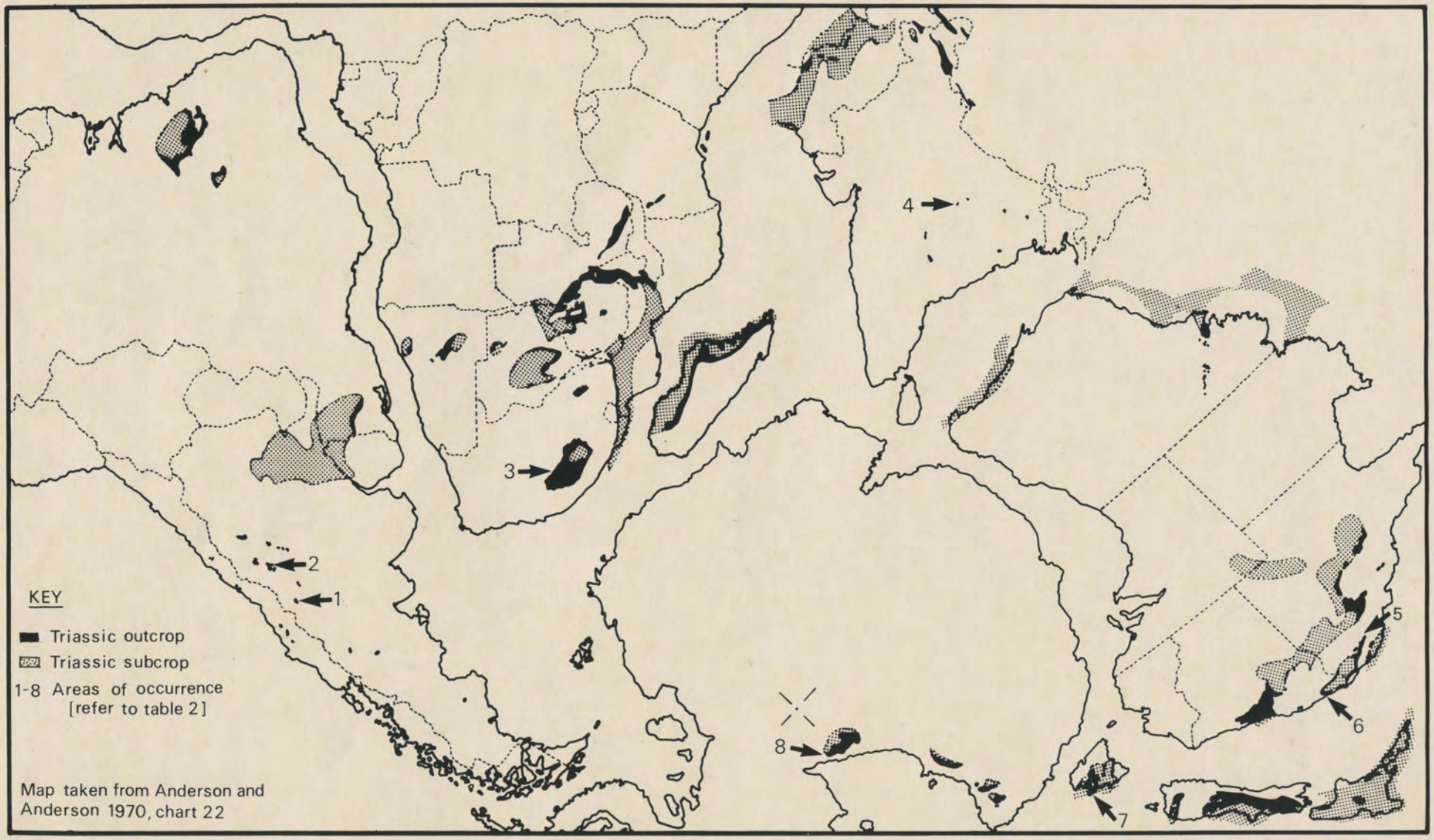

Figure 2. Distribution of *Podozamites elongatus* in Gondwanaland.

erland material compares favourably with *P.* aff. *eichwaldii* (Dolukenko, 1967) in being hypostomatic, of comparable cell size and the stomata being restricted to the areas between the veins, but differs in not having thickenings on the cell walls, in bearing papillae and in having the stomata randomly to longitudinally rather than transversely orientated. The four species described by Harris (1926, 1935) are less clearly known and close comparison is not possible. However, three of the species *(P. stewartensis, P. schenki* and *P. type 2)* bear papillae and in this respect are similar to the Molteno material. The species *(P. distans)* briefly described by Florin (1953) is similar in being hypostomatic and in having the stomata irregularly arranged, but differs in bearing no papillae.

(e) Molteno distribution, abundance and communities

During the present study *P. elongatus* was collected from 24 localities in the Molteno Formation (table 1). Four other localities (which could not be traced) are recorded in the literature (table 2). Relative abundance of *P. elongatus* at each locality is given in Table 1. *P. elongatus* together with the genera *Neocalamites* and *Dicroidium* are the most commonly preserved elements in the Molteno Flora (Anderson, 1974, table 3). The frequency of *Podozamites* at any particular locality is linked to the nature of the fossiliferous strata there. A few examples representative of the localities listed in Table 1 are provided.

At Little Switzerland and Upper Umkomaas one "uniform horizon" (i.e. fairly uniform in composition throughout) occurs and *P. elongatus* is found consistently but never as the dominant element.

N-L.Sw. — *Dicroidium* 73 %, *Podozamites* 3 %, new genus 17 %, and numerous other genera of frequency less than 2 %.

N-U.U. — *Dicroidium* 78 %, *Podozamites* 5 % and numerous other genera of frequency less than 3 %.

At Klein Hoek three "graded horizons" (each with a distinct plant community) which grade into one another occur:

upper horizon — *Neocalamites* 99 %
middle horizon — *Podozamites* 90 %
lower horizon — *Dicroidium* 45 %, *Podozamites* 40 % and *Taeniopteris* 10 % and four other genera of frequency less than 4 %.

At Rooipoort three "distinct horizons" (each with a different plant community) separated by barren strata occur:

upper horizon
C-Rp.IC — *Dicroidium* 84 %
middle horizon
C-Rp.IA — *Asterotheca* 50 %, Cycads 25 %
} no *Podozamites*
lower horizon
C-Rp.IB — *Podozamites* 95 %

At Konings Kroon two "distinct horizons", the lower one consisting of two "graded horizons", occur:

upper horizon
C-K.K.IA — *Dicroidium* 75 %, *Podozamites* 7 %
lower horizon
C-K.K.IB: upper — *Neoclamites* 100 %
lower — *Podozamites* 70 %

(f) Gondwana distribution (see fig. 2 & table 2)

Leaves very like those described from the Molteno occur in the Upper Triassic (Carnian) sediments (and from possible Lower Triassic in India) of all the Gondwana continents except Madagascar. The known distribution, based solely on illustrated specimens (except for Antarctica which is based on unpublished specimens in the foreign collection of Bernard Price Institute for Palaeontological Research), is recorded in Table 2 and Figure 2. Most of these records are of fragmentary leaves and in the absence of information to the contrary are all taken to be *P. elongatus.* Furthermore, abundance and association data are generally not available for these records.

TELEMACHUS ELONGATUS gen. et sp. nov.

Holotype
Collecting number: C-T.S. 11a, b.
Publication number: PB 326a, b.
Telemachus Spruit, Molteno Formation, Plate 2 (1, 2).

Reference collection

Telemachus Spruit, one nearly complete cone (Plate 2 (1, 2)); three portions of cone (Plate 2 (3, 7)); three groups of detached ovuliferous scales (Plate 2 (4–6)). The collection from this locality was selected as it yielded particularly clearly preserved cones although a greater number of specimens are available from Klein Hoek.

Diagnosis (based on reference collection)

Ovulate cone, length up to 60 mm, diameter of axis plus ovuliferous scale 25 mm and with full extent of bracts 60 mm. Axis woody, length up to 50 mm, diameter 4 mm and bearing spirally attached ovuliferous scales. Ovuliferous scale, five lobed, robust, woody, length up to 11 mm, slightly expanded at base 2 mm wide, central portion 3–4 mm long and 1–1,5 mm wide, apical area 5 mm wide. Lobes acute, length 1,5–3 mm and base 0,6 mm wide. Sterile bract narrowly lanceolate 30 mm long, greatest width 3 mm, margin faintly dentate towards proximal end otherwise entire, attachment uncertain.

Discussion
(a) Generic name

Four genera of broadly similar cones *(Tricranolepis, Cycadocarpidium, Borysthenia* and *Swedenborgia)* generally found associated with *Podozamites* leaves

occur in Middle Triassic to Lower Jurassic strata of Laurasia. They are most commonly recorded from the Norian-Hettangian of countries ranging from Greenland eastwards to Japan and to date are notably unrecorded from Gondwanaland. These genera are listed with their geographic and stratigraphic ranges in Table 3. The Molteno cones found in association with *Podozamites* are clearly related to the Laurasian material. They, however, differ in certain diagnostic features (table 4) from each of the four above-mentioned cone genera and are thus included in a new genus (named after the type locality).

(b) Specific name

The specific name *"elongatus"* refers to the characteristic elongate bracts.

(c) Illustrations

Plates 2 and 3 — Some of the most complete and best preserved specimens have been illustrated. Line drawings of three ovuliferous scales and two bract-scale complexes are included alongside the relevant photographs.

Plate 6 (1, 2) — *T. elongatus* in association with *P. elongatus* leaves.

Plate 6 (3) — *T. elongatus* in association with *D. elongatus*.

Plate 7 — *T. elongatus* ovuliferous scales in association with *P. elongatus* and seeds.

(d) Description

The cones occur as virtually complete specimens (Plate 2 (1, 2, 10), Plate 3 (1, 2, 6–9)); as portions of cone ((Plate 2 (3, 7), Plate 3 (4, 5)); and with the components detached and isolated (Plate 2 (4–6), Plate 3 (3)). Certain cones are preserved with their long axis parallel to the bedding plane and on splitting these may yield a longitudinal section ((Plate 2 (1, 2), Plate 3 (6–7)), or a lateral view (Plate 3 (1)). The cones also occur with their long axis at right angles to the bedding plane and on splitting are exposed in cross section (Plate 2 (3, 10), Plate 3 (2, 4)) with the cone axis at centre and the ovuliferous scales and bracts radiating from it. Only one cone (Plate 2 (1, 2)) shows a peduncle (15 mm long) which is attached to a small portion of stem(?).

The ovuliferous scale probably always has 5 lobes although due to preservation this can only be seen in certain specimens (Plate 3 (8)). On some specimens at least four lobes are visible and the missing one (or more) is indicated by an appropriate space or incompleteness of scale (Plate 2 (4, 8, 11, 13)). The single cone from Konings Kroon IB has yielded a longitudinal section with certain of the ovuliferous scales in cross section (Plate 3 (6–7)) which indicate the presence of five lobes.

At Molteno I and Klein Hoek seeds are found loosely associated with the ovuliferous scales (Plate 7). In general size and shape these simple seeds compare well with those recorded for Laurasian cone genera (table 3). However, how these were possibly attached and the significance of circular depressions and other minor features on the ovuliferous scale (Plate 2 (11) must await the discovery of more study material.

The site and mode of attachment of the sterile bract to the ovuliferous scale or cone axis is not clear. The sterile bract is seen intact in cones from Matatiele I, Molteno I, Klein Hoek and Telemachus Spruit and is not present in those from Little Switzerland, Upper Umkomaas and Konings Kroon IB. The reason for this is not clear but may be related to maturity or preservation. There may also be some connection with the isolated scale *Dordrechtites elongatus* gen. et sp. nov. which does not occur at those localities where the cones bearing both ovuliferous scales and bracts were found (table 1).

(e) Cuticle

Little Switzerland and Upper Umkomaas (each with a single cone specimen) are the only localities which may yield cuticle, but no studies have as yet been attempted.

(f) Molteno distribution

The cones and isolated ovuliferous scales are known from a total of nine localities (table 1). At Molteno I, Klein Hoek and Telemachus Spruit they occur in close association with *Podozamites* leaves.

DORDRECHTITES ELONGATUS gen. et sp. nov.

Holotype

Collecting number: C-Dt.II 365.
Publication number: PB 337.
Dordrecht II (Bird's River), Molteno Formation, Plate 4(1).

Reference collection

Dordrecht II, 33 specimens of which 26 are illustrated (Plate 4). The collection from this locality was selected as the scales are particularly clearly preserved. A greater abundance of scales is found, however, at both Zastron and Konings Kroon IB.

Diagnosis (based on reference collection)

Isolated T-shaped scale. Arms of T gracile and curving downwards to varying degree, each on average 18 mm long and 1 mm wide. Trunk of T robust and woody, tapering to a point, on average 11 mm long and greatest width on average 5 mm.

Discussion

The T-shaped structure is reminiscent of the reproductive structure of certain modern gymnosperms. In the cycadales the genera *Encephalartos, Ceratozamia* and *Zamia* have a T-shaped microsporophyll. In the Coniferales many of the microsporophylls show a basic T structure and the megasporophyll of *Cedrus deodara* is T-shaped with a flange of tissue spanning the arms of the T.

(a) Generic and specific name

As far as the author is aware no structures comparable to these scales have been described to date. The genus is named after the type locality Dordrecht II

and the species after the elongate scale arms.

(b) Illustrations

Plate 4 — illustrates most of the reference collection.

Plate 5 — a selection of scales from three localities showing variation in size, form and preservation is shown.

Plate 6 (3, 4), Plate 8 (3) — accumulations of scales associated with *Podozamites* leaves are shown.

(c) General description

The three-dimensional structure and the function of the scales are not clear at present.

Two factors indicate that they possibly derive from a cone. On many slabs a mass of scales occurs (Plate 6 (4), Plate 8 (3)), which suggests detachment from a common axis, but could also be the result of concentration by water or wind prior to fossilization. Some slabs show roughly parallel aligned pairs of scales (Plate 4 (18, 20), Plate 5 (1, 7)) which may also be due to chance. On one of these (Plate 5 (1)) occurs a woody axis from which the pair of scales appear to originate but there is no evidence of attachment.

(d) Cuticle

Little Switzerland is the only locality which might yield cuticular structure, but no studies have been made.

(e) Molteno distribution

D. elongatus occurs at seven localities in the Molteno Formation (recorded with abundance data in table 1). At Konings Kroon IB and Zastron it occurs in close association with *P. elongatus* leaves.

ASSOCIATIONS

Records of association in Laurasia

As far as possible all the known occurrences of the four cone genera mentioned earlier, almost invariably found associated with *Podozamites,* have been documented in Table 3. The only cone genus for which no association has so far been recorded is *Tricranolepis* and this has been included in Tables 3 and 4 as it shows comparable structure to the others. The better documented cases of *Podozamites* and cone association are briefly mentioned.

From the Rhaeto-Liassic of Scoresby Sound, East Greenland, Harris (1935) recorded *Cycadocarpidium* and *Swedenborgia* from seven localities each (two localities in common), at all of which *Podozamites* was abundant. Kon'no (1944, p. 28) noted that "cones and isolated scales of *Swedenborgia*" always occur in a heap of *Podozamites* leaflets ". . . [and] . . . shoots" in the lower Daidô System, Rhaeto-Liassic of Korea. Kon'no (1961) described various species of *Cycadocarpidium* from the Yamaguchi Prefecture, Japan (localities range in age through the Norian), and linked these with various species of *Podozamites.* Recently Stanislavsky (1976, p. 136) described *Podozamites toretziensis* and *Cycadocarpidium toretziensis* in organic connection in at least three specimens from an Upper Triassic (Norian) locality in the Donets Basin, U.S.S.R.

Records of association in the Molteno Formation

(a) Leaf and cone

The cones or detached bract-scale complexes of *T. elongatus* occur in close association with *P. elongatus* at Molteno I, Klein Hoek and Telemachus Spruit (table 1, Plate 6 (1, 2), Plate 7 (1–4)). At Little Switzerland, Upper Umkomaas, Matatiele I, Konings Kroon IB and Vineyard III the association is less clear due to the isolated occurrence of the cones or bract-scales (table 1).

(b) Leaf and scale

The scales of *D. elongatus* occur in close association with *P. elongatus* at Konings Kroon IB and Zastron. Masses of these scales occur on certain slabs with the leaves (Plate 6(4)). At both these localities *P. elongatus* is the dominant element with the few other genera being rare (Anderson, 1974, table 3). These scales also occur at Little Switzerland, Sani Pass, Mount Fletcher, Dordrecht II and Rouxville II but due either to the low number of scales found or to the diversity of the flora, the association is not obvious.

(c) Cone and scale

At only two localities, Konings Kroon IB and Little Switzerland, do both the cone *T. elongatus* (one specimen in each case) and the scales *D. elongatus* occur (table 1). At Konings Kroon IB the single cone (Plate 3 (6–7)) occurs in a slab alongside numerous scales (Plate 6 (3)) while at Little Switzerland (single unfigured cone?) there is no direct association. Both these cones are bractless and consist simply of an axis with attached ovuliferous scales. There is a notable absence of *D. elongatus* from Matatiele I, Molteno I, Klein Hoek and Telemachus Spruit at which the cones *T. elongatus* are preserved with the bracts and ovuliferous scales still attached to the cone axis. This suggests a posssible link between the bracts of *T. elongatus* and the scales of *D. elongatus.*

(d) Leaf, cone and seed

Simple seeds are found in close association with *T. elongatus* and *P. elongatus* at Klein Hoek and Molteno I (Plate 7 (1–5)). On one of the slabs from Klein Hoek a seed is seen lying abreast an ovuliferous scale (Plate 7 (4–5)). This type of seed has not been found at any of the other localities listed in Table 1.

(e) Leaf and trunk

At two localities, Lagg and Mount Fletcher, horizons consisting only of *P. elongatus* leaves (interstratified with thin barren strata) abut against vertically orientated silicified tree trunks which appear to be preserved *in situ.* Study of this wood and more detailed field studies remain to be undertaken.

(f) Leaf and root

At Rooipoort IB at least seven cycles consisting of an horizon of *P. elongatus* leaves followed by roots and barren rock occur.

Consideration of other possible associations in the Molteno Formation

(a) Podozamites with other fertile structures

At the localities listed in Table 1 many other fertile structures (i.e. besides those here described)

occur. Most of these are readily associated with other leaf genera (Anderson, 1974, table 2). Of the remainder, two cone-like structures need consideration. Cones described as *Conites charpentier* Zeiller by Du Toit (1927) have been collected from five localities (Little Switzerland, Sani Pass, Matatiele I, Vineyard III and Rouxville I) at which *Podozamites* also occurs. A relatively low abundance of *Podozamites*, however, occurs at these localities (table 1) and no association is indicated.

From the Lagg locality undescribed seed-bearing scales (seven specimens) have been found. These show similarities to *Rigbya arberioides* described by Lacey *et al.* (1975) from the Upper Permian *Daptocephalus* zone of the Karoo Basin. *Rigbya* was regarded by Lacey *et al.* (1975) as a female pteridosperm fructification and they also stated "there are no indications that they belong to the Glossopteridaceae, though this is possible". However, without further evidence *Rigbya* and the Molteno seed-bearing scales could also be regarded as belonging to the Coniferales.

It may, therefore, be considered unlikely that any other available fertile structures are associated with *Podozamites*.

(b) T. elongatus and D. elongatus with other leaf genera

Of the leaf genera (besides *Podozamites)* in the Molteno only those in the groups Cycadophyta and Coniferophyta need consideration as the other groups do not produce cone-like structures. The number of species in these two groups occurring at each locality is listed in Table 1.

T. elongatus. Only at Matatiele I, Molteno I, Klein Hoek and Telemachus Spruit have more than solitary specimens of the cone been obtained. At these localities conifers (other than *Podozamites)* and cycads are either absent or noticeably rare both in absolute numbers and in diversity.

D. elongatus. At Konings Kroon IB and Zastron, the two localities at which the scales occur abundantly (well over 50 specimens) cycads and conifers are absent.

Thus at present, aside from *Podozamites*, there is no indication of these fertile structures being associated with any other genera.

CONCLUSION

This paper has purposefully been limited to a description of the fossils and their occurrence with little or no stress on interpretation of structures, both from the Molteno and elsewhere. It is felt that further collecting would yield the material necessary to facilitate interpretation on aspects of maturity and function. *Podozamites* and the associated fertile structures require revision on a global scale.

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REFERENCES

ANDERSON, H. M. (1974). A brief review of the Flora of the Molteno Formation (Triassic), South Africa. *Palaeont. afr.*, **17**, 1–10.

———— (1976). *A revision of the genus Dicroidium from the Molteno Formation.* Unpublished Ph.D thesis, University of the Witwatersrand.

———— and ANDERSON, J. M. (1970). A preliminary review of the biostratigraphy of the uppermost Permian, Triassic and lowermost Jurassic of Gondwanaland. *Palaeont. afr.*, **13**, 1–22. Charts 1–22.

ANTEVS, E. (1919). Die Liassische Flora des Hörsandsteins. *K. Svenska Vetensk-Akad. Handl.*, **59(8)**, 1–69.

DOLUDENKO, M. P. (1967). Epidermal structure of *Podozamites* leaves. *Int. Geol. Rev.*, **9(2)**, 214–217.

DU TOIT, A. L. (1927). The fossil flora of the Upper Karroo beds. *Ann. S. Afr. Mus.*, **22(2)**, 289–420.

FEISTMANTEL, L. (1889). Übersichtliche Darstellung der Geologisch-Palaeontologischen Verhältnisse Sud-Afrikas. Th.1 Die Karroo-Formation und die dieselbe unterlagernden Schichten. *Abh. K. Bohm Ges. Wiss. Prague.*, **7(3)**, 1–89.

FLINT, J. E. and GOULD, R. E. (1975). A note on the Fossil Megafloras of the Nymboida and Red Cliff coal measures, Southern Clarence-Moreton Basin, N.S.W. *J. Proc. R. Soc. N.S.W.*, **108**, 70–74.

FLORIN, R. (1953). On the morphology and taxonomic position of the genus *Cycadocarpidium* Nathorst (Coniferae). *Acta Horti Bergiani*, **16(9)**, 257–275.

HARRIS, T. M. (1926). The Rhaetic Flora of Scoresby Sound, East Greenland. *Meddr. Gronland*, **68**, 46–148.

———— (1935). The fossil flora of Scoresby Sound, East Greenland. Pt 4 Ginkgoales etc. *Meddr. Gronland*, **112(1)**, 1–176.

JAIN, R. K. and DELEVORYAS, T. (1967). A middle Triassic flora of the Cacheuta formation from Minas de Petroleo, Argentina. *Palaeontology*, **10(4)**, 564–589.

JOHNSTON, R. M. (1888). *A systematic account of the geology of Tasmania.* Hobart, Government printer. 408 pp.

JONES, O. A. and DE JERSEY, N. J. (1947). The flora of the Ipswich coal measures — morphology and floral succession. *Pap. Dep. Geol. Univ. Qd.*, n.s., **3(3)**, 1–88.

KON'NO, E. (1944). Contribution to our knowledge of *Swedenborgia. Jap. J. Geo. Geog.*, **19**, 27–66.

———— (1961). Some *Cycadocarpidium* and *Podozamites* from the Upper Triassic formations in Yamaguchi prefecture Japan. *Sci. Rep. Tôhoku Univ.*, sec. ser. geol. **32(2)**, 195–212.

KRÄUSEL, R. (1959). Die Juraflora von Sassendorf bei Bamberg II Samenpflanzen. *Senckenbergiana lethaea.*, **40(1–2)**, 97–136.

KURTZ, F. (1921). Atlas de plantas fósiles de la Repúlica Argentina. *Actas Acad. nac. Cienc. Córdoba.*, **7**, 129–158.

LACEY, W. S., VAN DIJK, D. E. and GORDON-GRAY, K. D. (1975). Fossil plants from the Upper Permian in the Mooi River district of Natal, South Africa. *Ann. Natal Mus.*, **22(2)**, 349–420.

LELE, K. M. (1961). Studies in the Indian Middle Gondwana flora. 2: Plant fossils from the South Rewa Gondwana basin. *Palaeobotanist*, **10(1 and 2)**, 69–83.

MENENDEZ, C. A. (1951). La flora Mesozoica de la formación Llantenes (Provincia de Mendoza). *Revta Inst. nac. Invest.*

Cienc. nat. Mus. argent. Cienc. nat. Bernardino Rivadavia. Ciencias Botánicas, **2**(3), 147–261.

MORRIS, J. (1845). In: De Strezelecki, P. E., Ed., *Physical description of New South Wales and Van Diemans Land.* London, Longman, Brown and Green, 245–254.

NATHORST, A. G. (1911). Über die Gattung *Cycadocarpidium* Nath. nebst enigen bemerkungen uber *Podozamites. K. Svenska Vekensk-Akad. Handl.,* **46**(8), 1–11.

PRYNADA, V. D. (1940). On the find in the Urals of remarkably well preserved plants of Upper Triassic age. *Sov. Bot.,* **4**, 23–27 (in Russian).

ROSELT, G. (1958). Neue koniferen aus dem Unteren Keuper und ihre Beziehungen zu verwandten fossilen und rezenten. *Wiss. Z. Friedrich Schiller — Univ. Jena Mathematisch-naturwissenschaftliche Reihe,* **7**(4/5), 387–397.

SEWARD, A. C. (1903). The fossil floras of Cape Colony. *Ann. S. Afr. Mus.,* **4**(1), 1–122.

STANISLAVSKY, F. A. (1976). *Middle Keuper Flora of the Donets Basin.* Academy of Sciences Ukrain USSR, Geological Sciences, 168 pp. (in Russian).

SZE, H. C. (1931). Beiträge zur Liassischen flora von China. *National Research Institute of Geology Memoire No. 12 Shanghai.* Not seen, taken from Harris, 1935.

———— (1949). Die mesozoische Flora aus der Hsiangchi Kohlen Serie in West Hupeh. *Palaeont. sin.* N.s.A No. 2. Whole Series No. 133, 71 pp.

TAKAHASHI, E. (1952). *Swendenborgia* from Nariwa Oakayama prefecture. *J. Geol. Soc. Japan,* **58**(686), 522.

TENISON-WOODS, J. E. (1883). On the fossil flora of the coal deposits of Australia. *Proc. Linn. Soc. N.S.W.,* **8**, 1–131.

TRALAU, H. (1968). Evolutionary trends in the genus *Ginkgo. Lethaia,* **1**(1), 63–101.

WEBER, R. (1968). Die fossile flora der Rhät-Lias-Übergangsschichten von Bayreuth (Oberfranken) unter besondere Berücksichtigung der Coenologie. *Erlanger geol. Abh.,* **72**, 1–73.

ZEILLER, R. (1903). Flore fossile des gîtes de charbon du Tonkin. *Étud. Gîtes minér.,* Fr., **8**, 1–328.

TABLE 1

Podozamites elongatus, Telemachus elongatus, Dordrechtites elongatus.

Distribution and Associations in Molteno Fm.

Locality	Code	*Podozamites elongatus**	*Telemachus elongatus***					*Dordrechtites elongatus***	Tree trunks assoc.	Cycadophyta	Coniferophyta
			Fully articulate cone	Cluster of assoc. scales	Isolated scales	Bracts present	Seeds assoc.				
Little Switzerland	N–L.SW.	3 %	1					15		8 spp	1 sp
Upper Umkomaas	N–U.U.	5 %	1							5 spp	2 spp
Sani Pass	N–S.P.	5 %						11		1 sp	
Afsondering	C–Af.	5 %									1 sp
Matatiele II	C–Mt. II	✓									
Matatiele I	C–Mt. I	5 %	2		1					1 sp	
Mount Fletcher	C–M.F.	✓						1	✓		
Rooipoort IB	C–Rp. IB	95 %									
Konings Kroon I	C–K.K. IA	7 %								5 spp	1 sp
,, ,,	C–K.K. IB	70 %	1					>50			
Lagg	C–Lg.	10–70 %			2				✓		
Elliot	C–E.I	✓									
Dordrecht I	C–Dt. I	60 %									
Dordrecht II	C–Dt. II	10–90 %						33		1 sp	
Dordrecht III	C–Dt. III	✓									
Dordrecht IV	C–Dt. IV	✓									
Molteno I	C–Mo. I	78 %	1	1	4	✓	✓				
Klein Hoek	C–K.H.	1–90 %	6	2	11	✓	✓				1 sp
Telemachus Spruit	C–T.S.	75 %	4	3		✓					
Vineyard I	C–Vy. I	25 %								1 sp	
Vineyard III	C–Vy. III	5 %	1							1 sp	
Vineyard IV	C–Vy. IV	40–60 %									
Rouxville I	O–R.I	✓									1 sp
Rouxville II	O–R.II	0–100 %						3			
Zastron	O–Za. I	80 %						>50			

Key:

* Relative abundance of *Podozamites* at a locality is indicated as a percentage of total flora. Where "graded horizons" occur (see text) the range is indicated, e.g. C–K.H. 1–90 %.

** The numerals indicate number of specimens collected.

TABLE 2

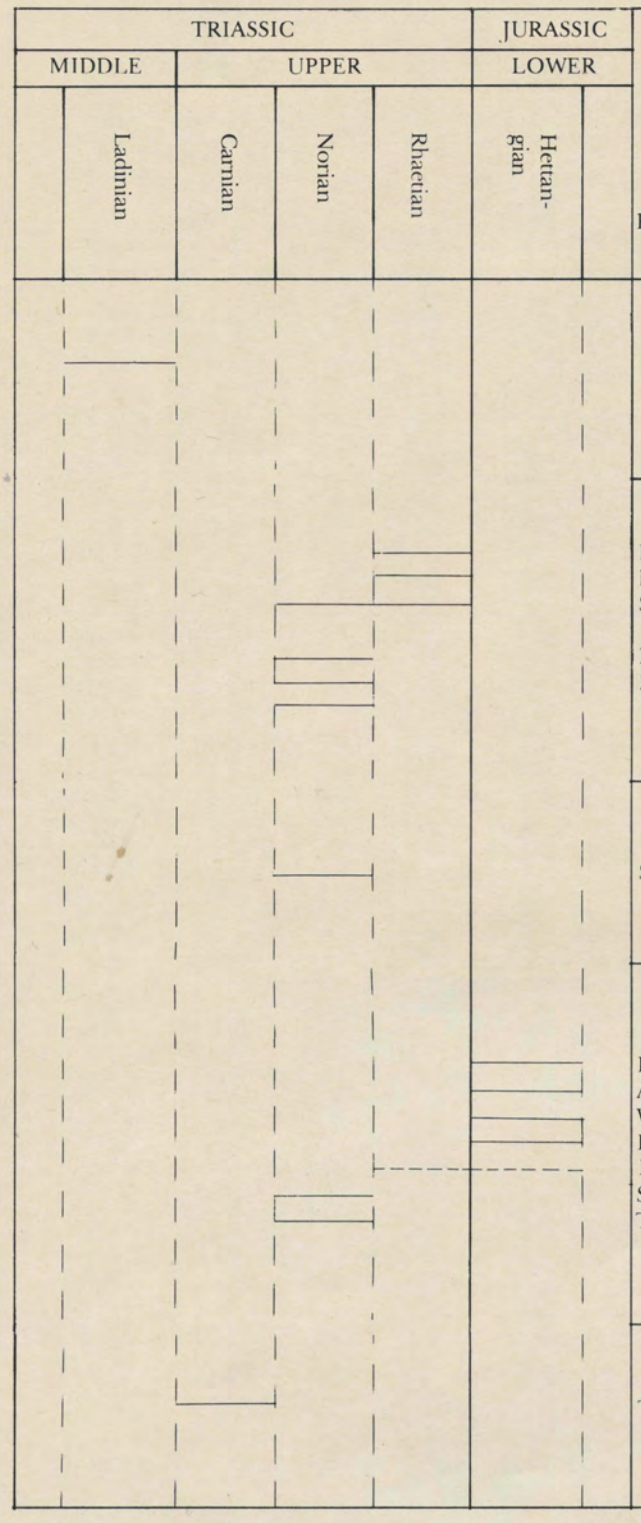
Podozamites elongatus — **distribution in Gondwanaland**

(All the listed specimens, except for the Indian material which is possibly L. Trias, derive from strata correlated with the Molteno Fm., L. Carnian, in Anderson & Anderson, 1970.

AUS 7	Morris, 1845	*Zeugophyllites elongatus* Morris 1845	pl. 4 (5, 5a)
AUS 5	Tenison-Woods, 1883	*Podozamites distans* Schimper (? date)	pl. 8 (3)
AUS 7	Johnston, 1888	*Zeugophyllites elongatus* Morris 1845	pl. 22 (1)
SAF 3	Feistmantel, 1889	*Podozamites (Zeugophyllites) elongatus* (Morris 1845) Feistmantel, 1889	pl. 2 (13), pl. 3 (3, 4, 7)
SAF 3	Seward, 1903	*Phoenicopsis elongatus* (Morris 1845) Seward, 1903	pl. 9 (1, 9, 10)
SAM 2	Kurtz, 1921	*Podozamites elongatus* (Morris 1845) Feistmantel, 1889	pl. 21 (181, 183–6, 315, 318, 320)
AUS 5	Jones and De Jersey, 1947	*Phoenicopsis elongatus* (Morris 1845) Seward, 1903	t–f. 57
SAM 1	Menendez, 1951	*Noeggerathiopsis* sp.	pl. 11 (1)
SAM 1	,,	*Podozamites elongatus* (Morris 1845) Feistmantel, 1889	pl. 12 (5)
SAM 1	,,	*Podozamites lanceolatus* (Lindley and Hutton 1836) Braun, 1843	pl. 12 (1)
SAM 1	,,	*Podozamites lanceolatus var. minor* (Schenk 1867) Menéndez, 1951	pl. 12 (2–4)
IND 4	Lele, 1961	*Desmiophyllum tachiatum* Lele 1961	pl. 4 (45–47)
SAM 2	Jain and Delevoryas, 1967	*Phoenicopsis elongatus* (Morris 1845) Seward, 1903	pl. 97 (1–2)
SAM 2	,,	*Podozamites lanceolatus var. genuinus* Heer, 1876	pl. 97 (6–8)
AUS 6	Flint and Gould, 1975	*Phoenicopsis elongatus* (Morris 1845) Seward, 1903	pl. 2 (6b)
ANT 8	(this paper)	*Podozamites elongatus* (Morris 1845) Feistmantel, 1889	—

TABLE 3

Geographic and stratigraphic distribution of the cone genera



Original Reference	Number of Localities	Geogr. & stratigr. data	
Roselt '58	2	Germ., Baden area, Lettenkohle.	TRICRANOLEPIS
Harris '35	7	E. Greenl., Scoresby, } *Lepidopteris* Z.	CYCADOCARPIDIUM
Nathorst '11	3	S. Sweden, Scania, }	
Stanisl. '76	2	USSR, Donets B., Protopivskaya & Novoraiskaya suites	
Prynada '40	1	USSR, Urals, Bogolovsk Mine	
Zeiller '03	?	N. Vietnam, Tonkin	
Kon'no '61	8	Japan, Yamaguchi Pref., several fms.	
Stanisl. '76	1	USSR, Donets B., Protopivskaya suite	BORYSTHENIA
Harris '35	7	E. Greenl., Scoresby }	SWEDENBORGIA
Antevs '19	?	S. Sweden, Scania }	
Weber '68	2	Germ., Franconia } *Thaumatopteris* Z.	
Kilpper '73 (p.c.)	?	Iran, Elburz }	
Kon'no '44	?	N. Korea, L. Daido System	
Sze '49	1	China, W. Hupeh, Hsiangchi Coalf.	
Takah. '52	1	Japan, Okayama Pref., Nariwa	
This paper	9	S. Africa, Karoo B., Molteno Fm.	TELEMACHUS

TABLE 4

Diagnostic features of the cone genera

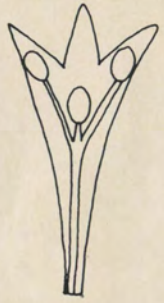
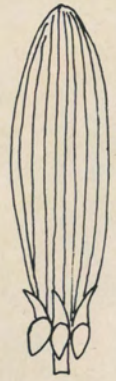
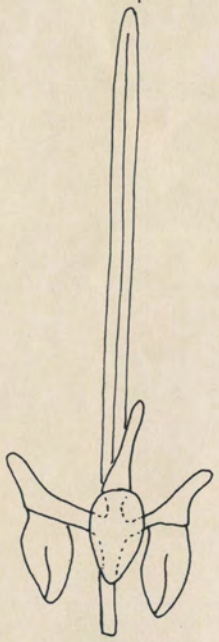
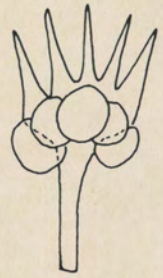
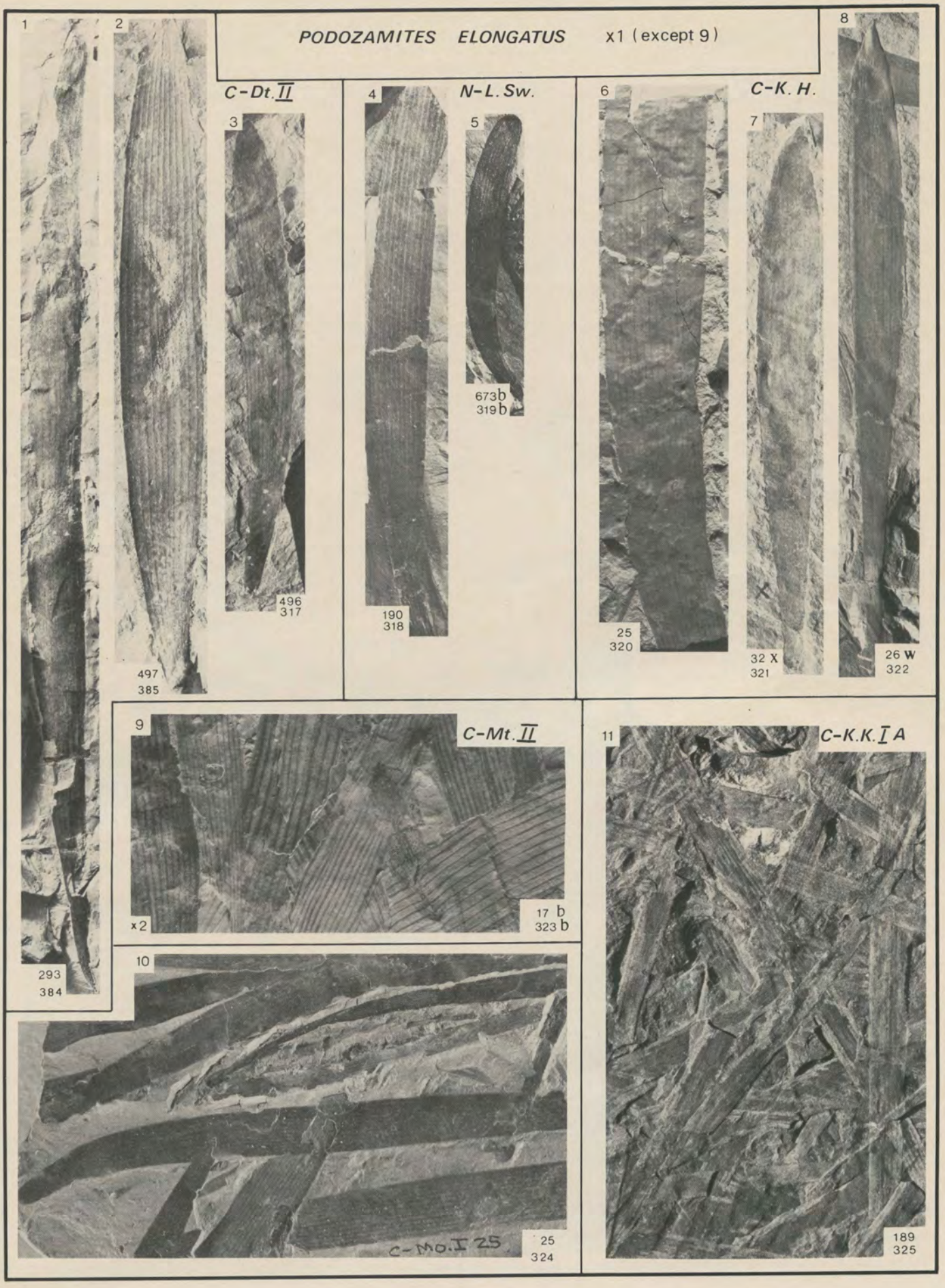
	TRICRANOLEPIS 3 spp.	CYCADOCARPIDIUM ±13 spp.	BORYSTHENIA 1 sp	SWEDENBORGIA ±8 spp.	TELEMACHUS 1 sp.
schematic diagram (Mag. 2X)	 *T. frischmannii* Roselt, 1958, fig. 6	 *C. tricarpum* Stanis., 1976, fig. 26A	 *B. fasciculata* Stanis., 1976, fig. 33I and 34F	 *S. attenuata* Kon'no, 1944, t–fig. 6	 *T. elongatus*
ovuliferous scale	trilobed, lobes acute and 3–4 mm long	bi- or trilobed, lobes acute and size variable	deeply trilobed and narrow, lobes elongate and obtuse 7 mm long	5 lobed, lobes acute and 3–6 mm long	5 lobed, lobes acute and 1,5–3 mm long
ovules (seeds)	1 or 3 ovules attached to expanded portion of scale	2 or 3 ovules attached to base of lobe	3 ovules attached $\frac{1}{3}$ to $\frac{1}{2}$ distance from base	5 ovules attached to base of lobes	?
sterile bract	unknown or not present	ovate to lanceolate, multiveined, size variable	elongate, apex acute single vein, 30 mm long and 1,5 mm wide	apparently absent however Harris (1935) records bract as "small outgrowth"	narrowly lanceolate, apex attenuate single vein, 30 mm long and 3 mm wide

PLATE 1


PODOZAMITES ELONGATUS x1 (except 9)
1
293
384
2
497
385
C-Dt. II
3
496
317
4
N-L. Sw.
190
318
5
673b
319b
6
25
320
C-K. H.
7
32 X
321
8
26 W
322
9
C-Mt. II
x2
17 b
323 b
10
C-MO. I 25
25
324
11
C-K.K. I A
189
325

TELEMACHUS ELONGATUS X2

1

11 a
326 a

2

11 b
326 b

3

134
327

7

116 a
329 a

4

C – T. S.

5

8 a
328 a

6

8 b
328 b

8

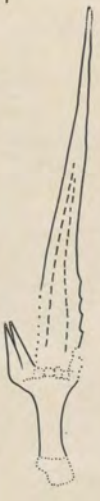
9

C – Mo. I

10

42 a
330 a

11



12

43 a
331 a

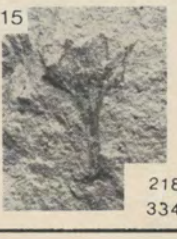
C – Lg.

13

14

A 2
333

15



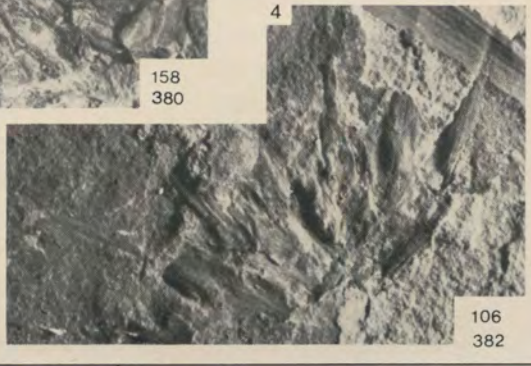
C – Mt. I

218 a
334 a

PLATE 3

TELEMACHUS ELONGATUS X2

C–K. H.



C - K. K. I B

N–U.U.

DORDRECHTITES ELONGATUS x 2 *C – Dt. II*

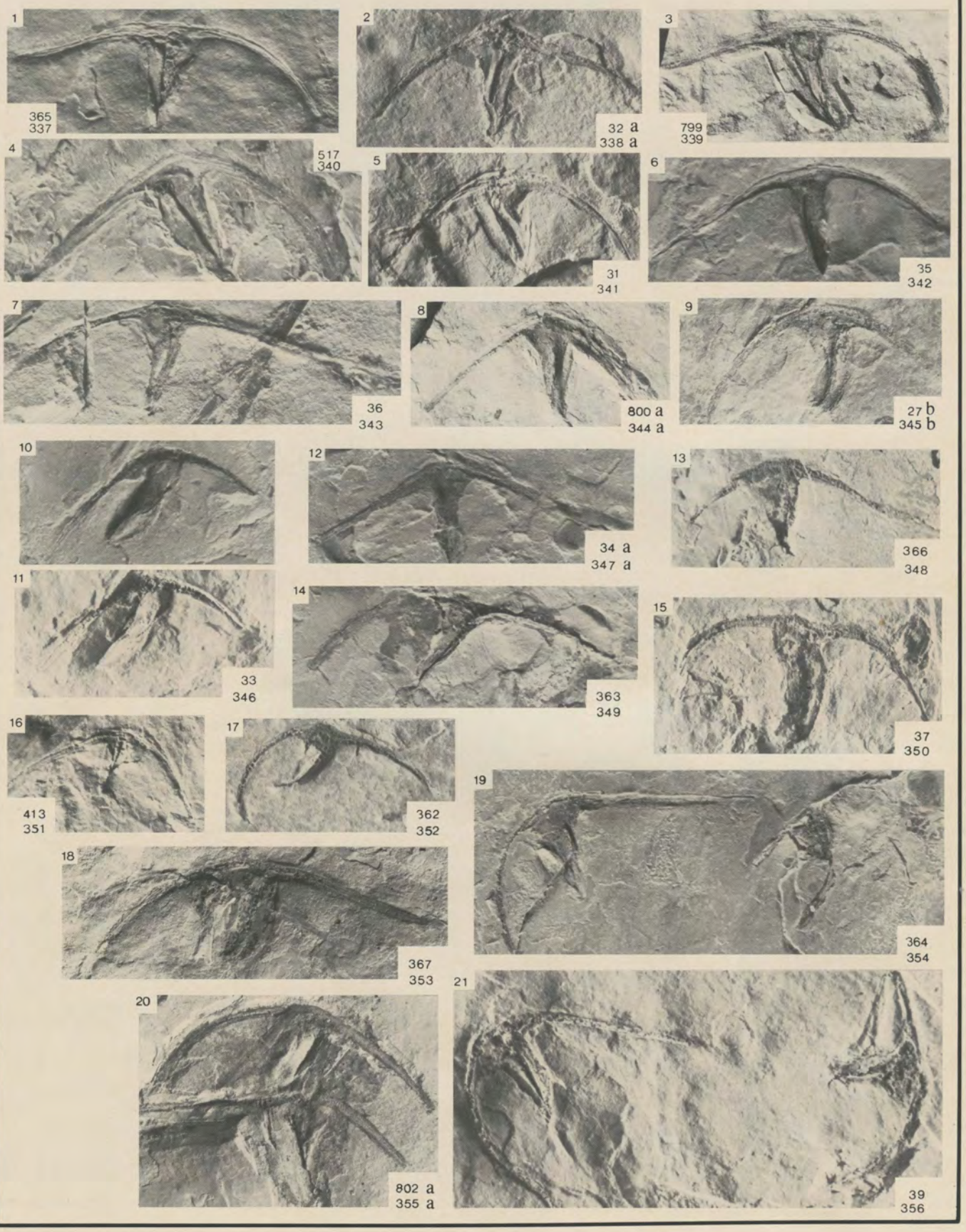
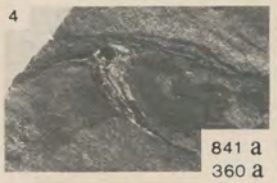


PLATE 5

DORDRECHTITES ELONGATUS x 2

N-L.SW



N-S.P.

O-Za.I

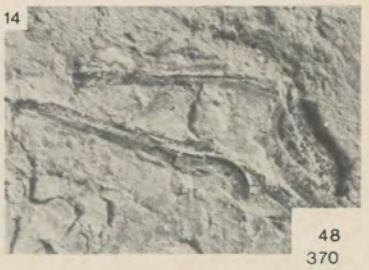


PLATE 6

PODOZAMITES ELONGATUS (*figs.* 1 - 4)

TELEMACHUS ELONGATUS (*figs.* 1–3)

1 C – K. H

X1

113
371

2 C – T S

X1

133
372

DORDRECHTITES ELONGATUS
(*figs.* 3 – 4)

3 C-K. K I B

X1

13 b
332 b

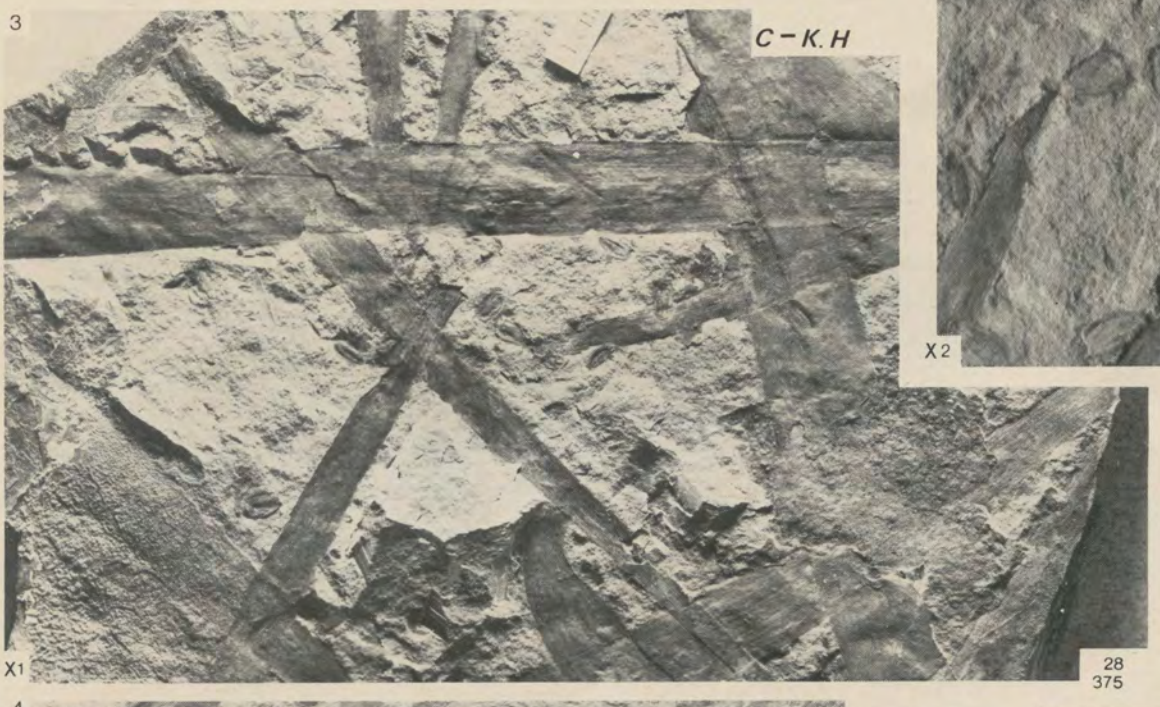
4 O-Za. I

$X\frac{1}{2}$

59 a
373

PLATE 7

PODOZAMITES ELONGATUS TELEMACHUS ELONGATUS AND SEEDS



PODOZAMITES ELONGATUS

1 C-T.S.

X½ 21 377

2 C-K.H.

X½ 27 378

DORDRECHTITES ELONGATUS

3 C-K.K. I B

X1 6 a 379 a

PLATE 9

PODOZAMITES ELONGATUS (*N–L. SW* 440 *'B' slide* 287)

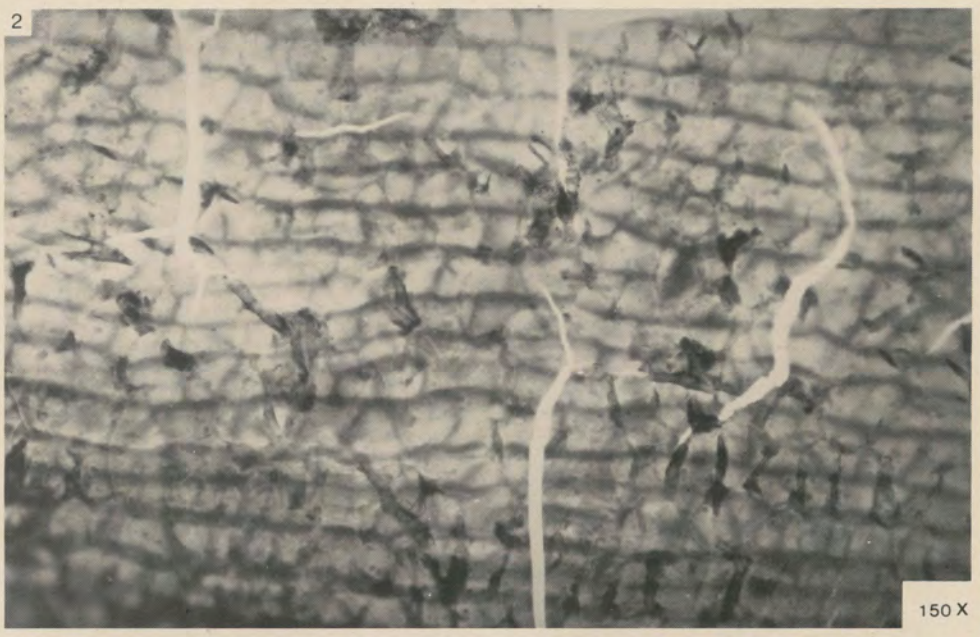
upper cuticle
figs. 1 – 2

1

50 X

lower cuticle
figs. 3 – 6

2

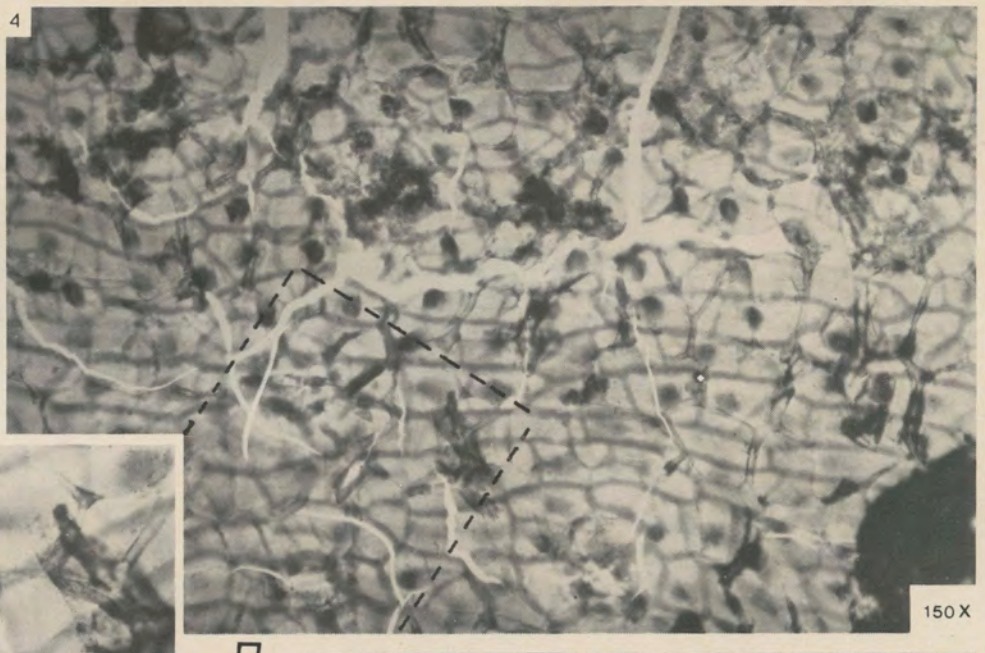


150 X

3

50X

4

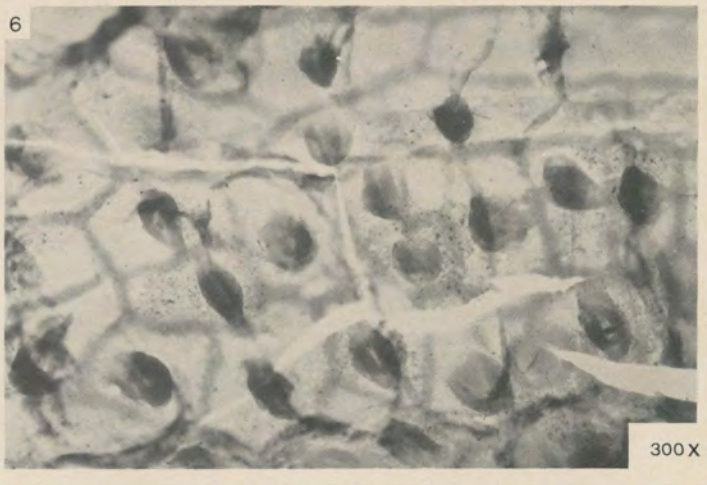


150 X

5

300 X

6



300 X