GYMNOSPERMOUS WOOD FROM THE KIMMERIDGIAN OF EAST SUTHERLAND AND FROM THE SANDRINGHAM SANDS OF NORFOLK

by G. T. CREBER

ABSTRACT. A description is given of the types of gymnospermous wood occurring in material collected from the Kimmeridgian of the East Sutherland coast. These types are compared with those collected from the Sandringham Sands of Norfolk. All of the material is described in terms of *biorecords* and *events*: references are made to previously described species in the form of *comparison records*. In traditional taxonomy some of the specimens are referable to *Cedroxylon* Kraus and the remainder to *Pityoxylon* Kraus. A close similarity is found between the two collections of wood providing a useful rough correlation of the base of the Sandringham Sands with the Kimmeridgian.

THE present work is based on two collections of gymnospermous wood; one from the Kimmeridgian of the East Sutherland coast and the other from the base of the Lower Portlandian of Norfolk (Sandringham Sands). The Scottish material consists of large calcareous petrifications from the shore at Helmsdale. The material from Norfolk is calcified in a highly ferruginous matrix and was obtained during the excavation of a drainage channel near West Dereham. The differing natures of the materials led to the use of two distinct techniques. Cellulose peels were made from the Helmsdale material but rock sections were prepared in studying the Sandringham Sands specimens as they required excessive etching time in attempts at making peels.

STRATIGRAPHY

The Sutherland material was collected mainly from the shore near Helmsdale where it is abundant; specimens occur with decreasing frequency northwards and southwards from Helmsdale along most of the outcrop of the Kimmeridgian from Kintradwell to Dun Glas. These wood specimens are most frequently encountered where there are outcrops of the boulder beds (Pl. 129, fig. 1). These remarkable beds consist of 'immense angular blocks and smaller waterworn stones of Middle Old Red Sandstone rocks embedded in a matrix of gritty, shelly limestone' (Phemister 1960). This matrix yields plant megafossil compression remains, a fauna of a littoral marine type with typical Kimmeridgian fossils and also some ammonites. Bailey and Weir (1933) considered that the breccias or boulder beds collected at the base of a submarine fault-scarp, the littoral shells and plant debris being swept down from the upthrow side together with Old Red Sandstone material by tsunamis or tidal waves energized by earthquakes along the fault.

It is only in comparatively recent years that the exact age of the Sandringham Sands of Norfolk has been worked out. Various excavations in the county have been of great assistance in providing exposures with ample fossil material. Larwood (1961) mentions the site where the Norfolk material described in this paper was found. Excavations

[Palaeontology, Vol. 15, Part 4, 1972, pp. 655–661, pls. 129–131.]

(TL 655997) immediately south-west of Abbey and West Dereham Station, about two miles to the east-north-east of Fordham, exposed part of the Sandringham Sands. The section exposed was about 6·5 m deep. The lower beds consisted of a conglomerate passing down into very pebbly dark grey sands; these rested on 1·5 m of blue-grey silty sands which formed the bottom of the section. Contractors' bore-logs for this locality show that the blue-grey silty sands, with occasional beds of harder cemented sandstone, continue below the visible base of the excavated section for at least 8 m, giving a thickness of about 16 m for the sands at this point. The blue-grey silty sands contained a layer of nodules; in the latter were large fragments of wood and phosphatized casts and moulds of many bivalves, some belemnites and occasional ammonites. Of the fossils Casey (1961) said that this part of the excavation revealed a suite indicative of a Berriasian (Infra-Valanginian) fauna new to Britain. He described the occurrence of the fossils in nodular masses of hard grey-brown glauconitic sandstone with carbonized plant debris about 10 m above the base of the formation. Included were species of *Hartwellia*, *Isocyprina* and *Isodonta* which have their closest parallels in the Upper Jurassic.

Further evidence for the age of the Sandringham Sands was provided by a section exposed by an excavation for a North Sea Gas pipeline near King's Lynn (TF 65 15). Casey and Gallois (1968) describe a previously unrecorded sequence of ammonite faunas in a facies of glauconitic sand and phosphate nodules. The genus *Subcraspedites* was succeeded by forms of the group of *Garniericeras tolijense* (Nikitin), diagnostic of the Uppermost Volgian of the Northern U.S.S.R., in turn succeeded by similar ammonites accompanied by an undescribed genus ancestral to the basal Cretaceous (Ryazanian) *Hectoroceras*; the sequence continued with *Hectoroceras* and *Surites*. In addition, Ager (1971) has strengthened the correlation of the Sandringham Sands with the Volgian of the U.S.S.R. in studies on the brachiopod genus *Rouilleria*.

The present work therefore lends considerable support to an Upper Jurassic age for the base of the Sandringham Sands, by showing that there is a very high degree of correlation between the gymnospermous woods of these beds and those of the Kimmeridgian of East Sutherland. The possibility has to be faced that in both the Sandringham Sands and in the Helmsdale Kimmeridgian the wood material might have been re-worked. However, in the case of the Norfolk material one piece of wood (MGC/T) shows borings by xylophagous crustacea (or mollusca) which are fresh and do not appear to have suffered the abrasion likely to have occurred in re-working. The largest pieces of wood seen at the Helmsdale locality measured 40 cm by 25 cm (Pl. 129, fig. 3). Associated with

EXPLANATION OF PLATE 129

Fig. 1. About eight square metres of the boulder beds on the shore at Helmsdale, polished by the sea and showing numerous clasts.

Figs. 2, 6. Biorecord 1 TRACHEIDOXYL *MS.* 2, Specimen MGC/T, a portion of a tangential longitudinal section with transverse sections of a number of rays, some of which are partially biseriate; ×150. 6, Specimen MGC/A, cross-field pits in a radial longitudinal section, the ray cells are filled with resin; ×150.

Fig. 3. Two large pieces of calcified wood, drilled by Recent rock-boring molluscs, on the storm beach at Helmsdale; length of hammer 30 cm.

Fig. 4. cfA 2 TRACHEIDOXYL *RC.* Specimen B 34/17, part of a tangential longitudinal section showing a fusiform ray with resin canal; ×150.

Fig. 5. cfA 1 TRACHEIDOXYL *MS.* Specimen B 34/9, large cross-fields pits seen in a radial longitudinal section passing along a ray; ×150.

the fossil corals referred to above is a large quantity of carbonized wood fragments up to 3 cm in diameter; connection between this wood and the petrified wood has not yet been demonstrated.

SYSTEMATIC SECTION

For description of the material use is made of the biorecord system of Hughes and Moody-Stuart (1969). A biorecord is defined as a conceptual taxon based on a specimen from a stated locality. The biorecord is not in essence different from a palaeontologic species at the stage of description by its originator, but differs in the use that can subsequently be made of it; virtually no literature search is involved and description priorities are not considered. The title heading and reference line for a biorecord (e.g. 1 TRACHEIDOXYL *MS*) consists of (*a*) a serial number which outside this paper would be preceded by an identifier such as author's initials, (*b*) an informal (but stored) classification guide, and (*c*) an author's working reference printed in italics to indicate that it is a 'non-search' item. The term TRACHEIDOXYL is used to indicate that the specimen involved is a detached portion of wood characteristically composed of tracheids with only a minor proportion of other tissues.

Additional specimens are listed as comparison records; those which cannot readily be distinguished from the biorecord are designated 'cfA'. Specimens of progressively lower grades of comparability then receive the prefix 'cfB' if there is one quantitative difference and 'cfC' in the case of further divergence.

BIORECORDS JUR 28 27 GB XYL

The above heading, in a form suitable for data storage, indicates that the biorecords are wood specimens from localities in the British Jurassic. The Ages/Stages are those used in the Fossil Record (Harland *et al.* 1967), numbered consecutively back from Recent. Thus 28 and 27 are the Oxfordian and Kimmeridgian, respectively. All specimens are lodged at the Sedgwick Museum, Cambridge.

1 TRACHEIDOXYL *MS*

Diagnosis. Growth rings well marked, 0·5 cm broad. Early wood tracheids cross-section 50 μm $\times$ 50 μm, reducing only slightly through the season which terminates with a few rows of very small elements. Bordered pits, 15 μm diameter, on the radial walls of the tracheids, uniseriate arrangement, sometimes contiguous and compressed. Rays uniseriate or partially biseriate, 2 to 20 cells in height, average 11 (Pl. 129, fig. 2). Cross-field with a solitary, large, oblique pit.

Record Specimens. MGC/A, MGC/B, MGC/Q and MGC/T from the Flood Relief Channel cut in the Sandringham Sands to the south and east of Abbey and West Dereham Station (TL/655997).

Description. This biorecord is readily distinguished by its highly characteristic cross-field pitting (Pl. 129, figs. 5 and 6), the 'eiporen' of the German authors.

Comparison Records. cfA 1 TRACHEIDOXYL *MS*: (1) *Metacedroxylon scoticum* described by Holden (1915) from the Kimmeridgian of Loth, East Sutherland; Sedgwick Museum Specimen No. K613. (2) Specimens B34/9 and B34/20 from Helmsdale, East Sutherland.

2 TRACHEIDOXYL *RC*

Diagnosis. Growth rings very variable in breadth, 1–3 mm. Early wood tracheid cross-section 40 μm × 40 μm. Marked zone of late wood, 12 rows of smaller dense elements. Bordered pits on tracheid radial walls 10–12 μm in diameter, bars of Sanio. Pits generally uniseriate but smaller and biseriate at ends of tracheids. Vertical (Pl. 130, fig. 1) and horizontal resin canals. Rays uniseriate or fusiform with resin canal, 2–20 cells in height, average 8. Cross-field with one to two small bordered pits.

Record Specimen. MGC/R from the Sandringham Sands (TL/655997).

Description. This biorecord is of considerable interest in that it possesses rays with fusiform cross-sections (Pl. 129, fig. 4) and bars of Sanio (Pl. 130, fig. 2) on the radial walls of the tracheids. It would appear that there is no other undoubted record of such a wood as early as the Kimmeridgian.

Comparison Records. cfA 2 TRACHEIDOXYL *RC*: Specimen B34/17 from Helmsdale, East Sutherland and 3 TRACHEIDOXYL *RD* (Specimen MGC/O) from the Sandringham Sands (TL/655997). cfB 2 TRACHEIDOXYL *RC*: *Piceoxylon scleromedullosum*, described by Shimakura (1937) from the Senonian of Sakhalin has many similar features to 2 TRACHEIDOXYL *RC*; a much closer comparison could be made if the preservation of 2 TRACHEIDOXYL *RC* would allow the certain determination of the existence of ray tracheids (there is some evidence of their presence but insufficient to include as an item in the diagnosis).

3 TRACHEIDOXYL *RD*

Diagnosis. Growth rings uniform, 0·5 cm broad. Early wood tracheids cross-section 60 μm (Rad) × 50 μm (Tan). Gradual transition to late wood through the ring. Bordered pits on tracheid radial walls 17 μm in diameter. Bars of Sanio. Pits generally uniseriate but occasionally biseriate at ends of tracheids. Vertical (Pl. 130, figs. 3 and 4) and horizontal resin canals. Rays uniseriate or fusiform with resin canal, 2–17 cells in height, average 9 (Pl. 130, fig. 5). Cross-field with one to two small bordered pits.

Record Specimen. MGC/O from the Sandringham Sands (TL/655997).

Distinction. This is very similar to biorecord 2 above. In order to avoid conflicting items in the diagnosis they are being maintained separately for the time being. It is fully realized that the differences may only be such as one might expect between pieces of wood from the inner and outer parts of the trunk or between branch and trunk. Collection of further material may elucidate the matter.

EXPLANATION OF PLATE 130

Figs. 1, 2. cfA 2 TRACHEIDOXYL *RC*. 1, Specimen B 34/17, a vertical resin canal seen in transverse section; × 150. 2, Specimen B 34/17, a portion of a radial longitudinal section showing bordered pits with bars of Sanio; × 150.

Figs. 3–5. Biorecord 3 TRACHEIDOXYL *RD*. Specimen MGC/O. 3, 4, vertical resin canals seen in transverse section; × 150. 5, part of a tangential longitudinal section showing a fusiform ray with resin canal; × 150.

Fig. 6. cfA TRACHEIDOXYL *CH*. Specimen K 571, a portion of a tangential longitudinal section showing one of the deep rays; × 150.

4 TRACHEIDOXYL *CH*

Diagnosis. Growth rings well marked, 0·1–0·5 cm broad. Rings sometimes subdivided by bands of smaller tracheids. Bordered pits on tracheid radial walls 17 μm in diameter, generally uniseriate but not infrequently biseriate and opposite (Pl. 131, fig. 1). Rays uniseriate, sometimes very large (Pl. 130, fig. 6), one to 34 cells high, average 16. Cross-field pitting one to four small pits, most frequently two.

Record Specimens. MGC/H and MGC/U from the Sandringham Sands (TL/655997).

Comparison Records. cfA 4 TRACHEIDOXYL *CH*: (1) *Cedroxylon hornei* described by Seward and Bancroft (1913) from Helmsdale shows clearly the characteristic cross-field pitting (Pl. 131, figs. 2 and 5) and curious variability in the growth rings (Pl. 131, fig. 4) which are such special features of this biorecord. (2) Sedgwick Museum Specimen No. K 571 from Helmsdale. (3) Specimens B 41/2 and B 34/13 from Helmsdale, East Sutherland.

5 TRACHEIDOXYL *GR*

Diagnosis. Very broad growth rings, 0·9 cm wide. Early wood tracheid cross-section 50 μm $\times$ 50 μm. Wide zone of late wood, about 1/3 of the ring, distorted and collapsed (Pl. 131, fig. 3). Bordered pits on radial tracheid walls 13 μm in diameter. Uniseriate arrangement, sometimes contiguous. Rays uniseriate 6–29 cells in height, average 15.

Description. This material is not very well preserved but it is represented in the Helmsdale collection by such striking hand specimens that it demands recognition. The most noticeable feature is the width of the growth rings some of which are nearly one centimetre wide. The most likely explanation is that the material originated from the heartwood of a very large trunk; sections of the modern *Sequoia gigantea* show at the centre growth rings of the calibre of this biorecord. Such fine detail as can be observed in the specimens would indicate that they are probably the central portions of trunks of 4 TRACHEIDOXYL *CH*.

Record Specimens. B34/1 and B41/1 from Helmsdale, East Sutherland.

GENERAL REMARKS

Although a number of attempts have been made to systematize the very large number of published species of fossil gymnospermous wood, exquisitely preserved material is often required for successful identification in the complicated keys involved. For example Kräusel (1949) published a key separating the various woods into 25 genera, many of the 27 dichotomies requiring the presence in the specimens of minute details. Further keys follow, dividing the genera into species: in some genera there are upwards of 20 species. Many of the latter have names which imply supposed relationships with modern species; the evidence for these relationships is frequently very scanty.

The aim of the present work is to depart as far as possible from the purely taxonomic approach and to attempt to use the material as a means of geological correlation. In this initial essay there would appear to have been considerable success. By using the biorecord system of Hughes and Moody-Stuart (1969) it has been possible, with material not especially well preserved, to show an essential similarity between the assemblages of gymnospermous wood from two widely separated localities. Further support has been provided for the correlation previously carried out by other workers on these localities.

However, if this technique is to be applied to a number of localities a certain measure of taxonomy may be desirable in order to appreciate the relative proportions of broadly different types of wood occurring in each. The following is proposed:

A. Wood with resin ducts normally present. This would comprise the species previously described under the generic names *Pityoxylon*, *Piceoxylon*, *Pinuxylon*, and further subdivisions of these as proposed by subsequent authors. The modern genera that fall unto this group are: *Pinus*, *Larix*, *Picea* and *Pseudotsuga*.

B. Wood with resin ducts only of traumatic origin, pits on the radial walls of the tracheids separate and circular and, if in two or more rows, opposite. Contiguous and more or less flattened pits may occur but never as a general rule. This would comprise the species previously described under the generic names *Cedroxylon*, *Cupressinoxylon*, *Mesembrioxylon*, and the various later sub-divisions of these genera. Modern genera in this category are: *Cedrus*, *Abies*, *Juniperus* and *Sequoia*.

C. Wood in which the pits on the radial walls of the tracheids are normally contiguous with their mutual boundaries flattened to form a polygonal pattern. These pits are usually multiseriate and alternate. This would comprise *Dadoxylon* and its later subdivisions. Examples of modern genera: *Agathis* and *Araucaria*.

This classification implies a considerable amount of 'lumping' as compared to the more complicated ones extant in the literature but for present purposes it would have a number of advantages. First, virtually all the available material could be classified; only the very lowest grade of preservation would fail to preserve the relatively major features necessary to place a specimen in its proper category. The relative proportions of the numbers of specimens in each group would serve as useful data in the process of correlating strata. A further advantage lies in the fact that it may prove possible to apply this method to wood preserved other than by petrification; that is to say, lignitic fragments and fusain.

EVENTS AND TIME-CORRELATION

Event: H — Helmsdale.
Woods of Type A: cfA 2 TRACHEIDOXYL *RC* (B 34/17).
Woods of Type B: Biorecord 5 TRACHEIDOXYL *GR* (B 34/1 and B 41/1).
cfA 1 TRACHEIDOXYL *MS* (B 34/9, B 34/20 and K613).
cfA 4 TRACHEIDOXYL *CH* (B 41/2, B 34/13 and K571).
Woods of Type C: None.
Woods indeterminate: 16 specimens.

EXPLANATION OF PLATE 131

Figs. 1, 2, 4. Biorecord 4 TRACHEIDOXYL *CH*. 1, Specimen MGC/U, biseriate pitting on the radial walls of a group of tracheids; ×150. 2, Specimen MGC/U, cross-field pitting seen in a radial longitudinal section passing through a ray; ×150. 4, Specimen MGC/H, a transverse section showing three 'false rings' produced in one season; the section shows the effect of drilling by xylophagous animals; ×90.

Fig. 3. Biorecord 5 TRACHEIDOXYL *GR*. Specimen 41/1, a transverse section showing a sector of one complete growth ring with the late wood collapsed and distorted; ×45.

Fig. 5. cfA 4 TRACHEIDOXYL *CH*. Specimen K 571, cross-field pitting seen in a radial longitudinal section; ×150.

Event: N — Norfolk.
Woods of Type A: Biorecord 2 TRACHEIDOXYL *RC* (MGC/R).
Biorecord 3 TRACHEIDOXYL *RD* (MGC/O).
Woods of Type B: Biorecord 1 TRACHEIDOXYL *MS* (MGC/A, MGC/B, MGC/Q and MGC/T).
Biorecord 4 TRACHEIDOXYL *CH* (MGC/H and MGC/U).
Woods of Type C: None.
Woods indeterminate: 5 specimens.

In both events woods of Type A are rare, especially at Helmsdale where only one out of 25 specimens is of this type. Of the 16 indeterminate specimens the preservation was at least sufficient to show that they were not of Type A. The proportion in the Norfolk event seems to be slightly larger with two out of 13 specimens.

It will be seen that these two wood-events are very similar but that there is no evidence to indicate which is earlier in time. However, the external evidence of time-correlation suggests that the Norfolk locality is Volgian whilst the Scottish one is probably Lower-Middle Kimmeridgian. The situation as regards the latter is much confused by considerable folding and faulting but the northernmost part of the outcrop (i.e. the Helmsdale area) is usually regarded as containing the higher beds.

Acknowledgements. I wish to thank Mr. N. F. Hughes for considerable assistance in the preparation of the manuscript. I am very grateful to the Governing Body of Emmanuel College, Cambridge, for the award of a Schoolmaster Fellow-Commonership which made possible my work at the Sedgwick Museum. I am also indebted to the Royal Society's Committee for Research in Schools for a grant to aid this work.

REFERENCES

AGER, D. V. 1971. The Brachiopods of the Erratic Blocks of Spilsby Sandstone in Norfolk and Suffolk. *Proc. Geol. Ass.* **82,** 393–401.

BAILEY, E. B. and WEIR, J. 1933. Submarine Faulting in Kimmeridgian Times: East Sutherland. *Trans. Roy. Soc. Edin.* **57,** 429.

CASEY, R. 1961*b*. The Geological Age of the Sandringham Sands. *Nature*, London, **190,** 1100.

—— 1967. in Annual Report (for 1966). *Inst. of Geol. Sciences*, London, 90–91.

—— and GALLOIS, R. W. 1968. in Annual Report (for 1967). *Inst. of Geol. Sciences*, London, 104–105.

HARLAND, W. B. *et al.* (Eds.). 1967. The Fossil Record. London (Geological Society), xii+828 pp.

HOLDEN, R. 1915. A Jurassic Wood from Scotland. *New Phytologist*, **14,** 205–209.

HUGHES, N. F. and MOODY-STUART, J. C. 1969. A method of stratigraphic correlation using early Cretaceous spores. *Palaeontology*, **12,** 84–111.

KRÄUSEL, R. 1949. Die fossilen Koniferenhölzer; Teil II. *Palaeontographica* **B 89,** 83–203.

LARWOOD, G. P. and FUNNELL, B. M. (Eds.). 1961. The Geology of Norfolk. *Trans. Norfolk and Norwich Nat. Hist. Soc.* **19,** Pt. 6, 270–375.

PHEMISTER, J. 1960. Scotland: The Northern Highlands. *Inst. of Geol. Sciences*, London, 89–90.

SEWARD, A. C. and BANCROFT, N. 1913. Jurassic plants from Cromarty and Sutherland, Scotland. *Trans. Roy. Soc. Edin.* **48,** 867.

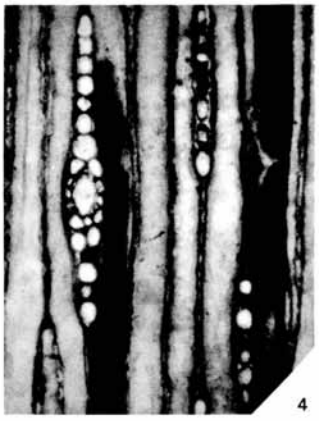
SHIMAKURA, M. 1937. Studies on fossil woods from Japan and adjacent lands. *Sci. Rep. Tohoku Imp. University*, 2 Geol., **19,** No. 1, 28.

G. T. CREBER
University College School
Hampstead
London


1


2

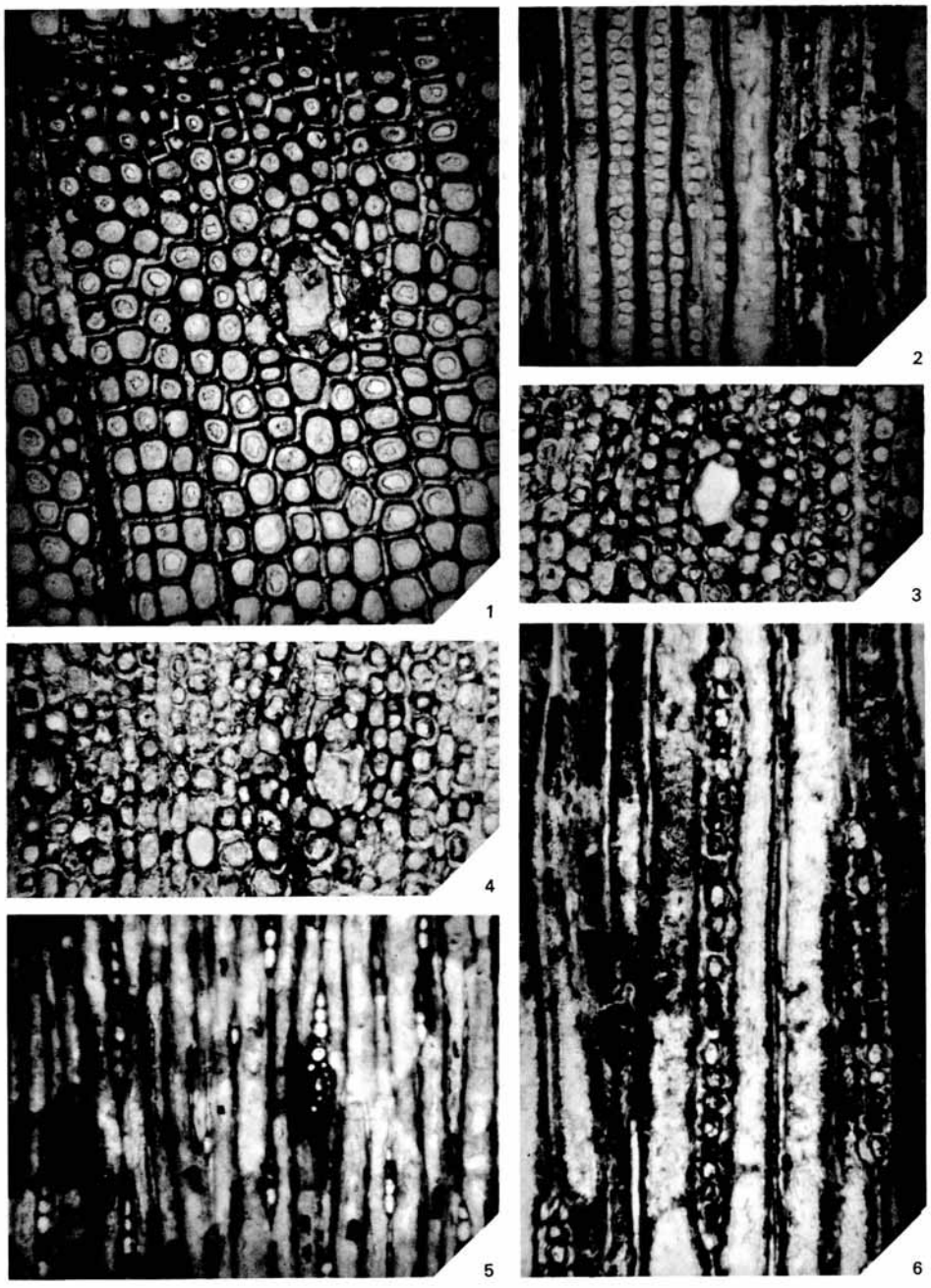

3


4

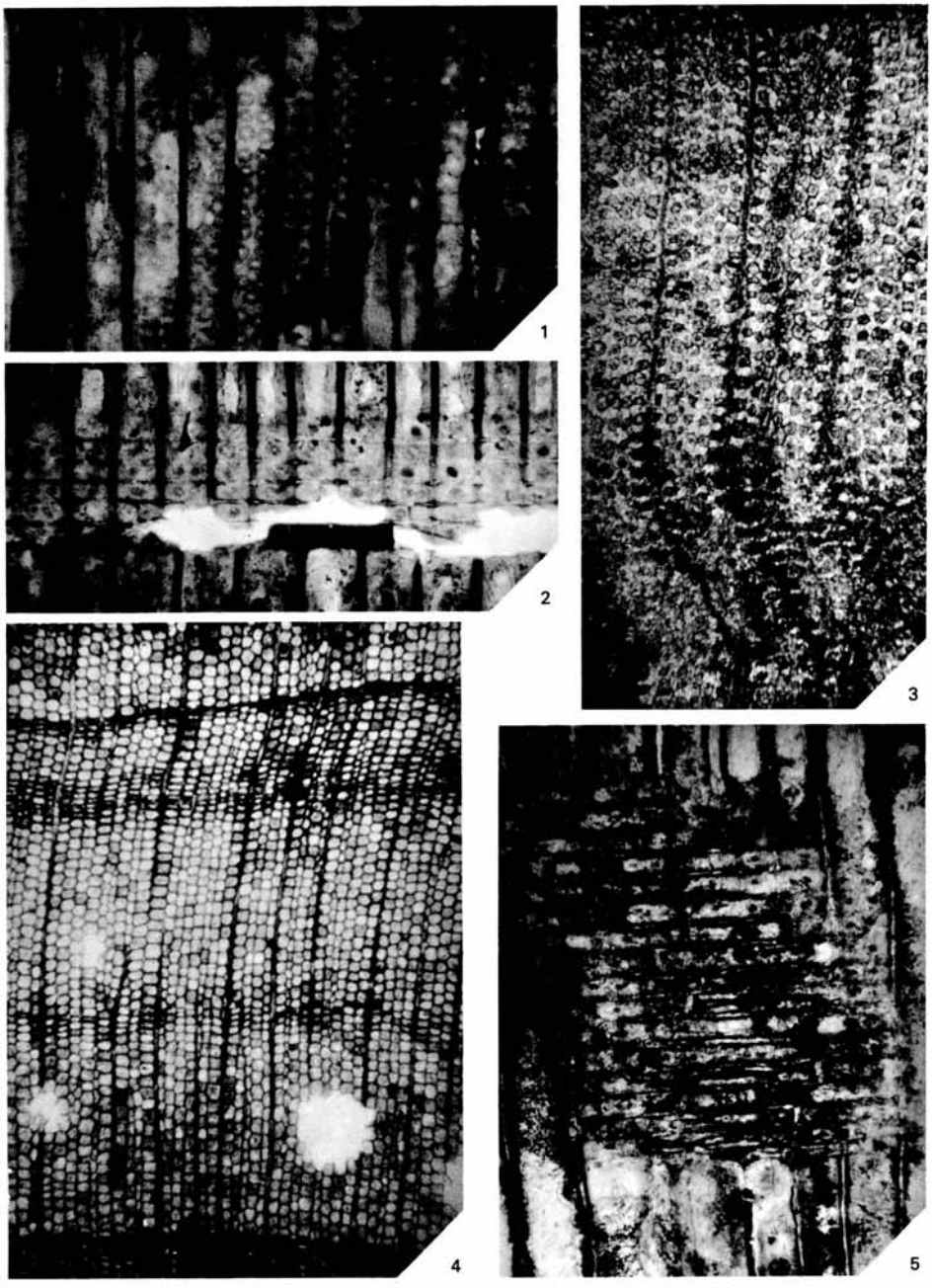

5


6

CREBER, Late Jurassic petrified wood



CREBER, Late Jurassic petrified wood



CREBER, Late Jurassic petrified wood