ON SOME CONIFEROUS CONES, PROBABLY OF *BRACHYPHYLLUM*, FROM THE JURASSIC OF THE RAJMAHAL HILLS, BIHAR, INDIA,

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Introduction.

During the last two excursions in 1948 and 1950 we collected some plant fossils from a ferruginous oolite of Jurassic age in Amarjola in the Amrapara district, Bihar. Of these fossils some leafy branches referred to the genus *Brachyphyllum* have already been studied by one of us (Bose). In continuation with that we examined some detached coniferous cones, which were considered most probably to belong to the same genus. These are poorly preserved and are rather crumbly. With the aid of strong light and under immersion in xylol we were able to examine the surface of the outer epidermis of the cone scales. After boiling in Canada balsam these cones could easily be cut and ground into thin sections. Thus we were able to study, besides the external morphology, the internal anatomy also, which was so far very little known.

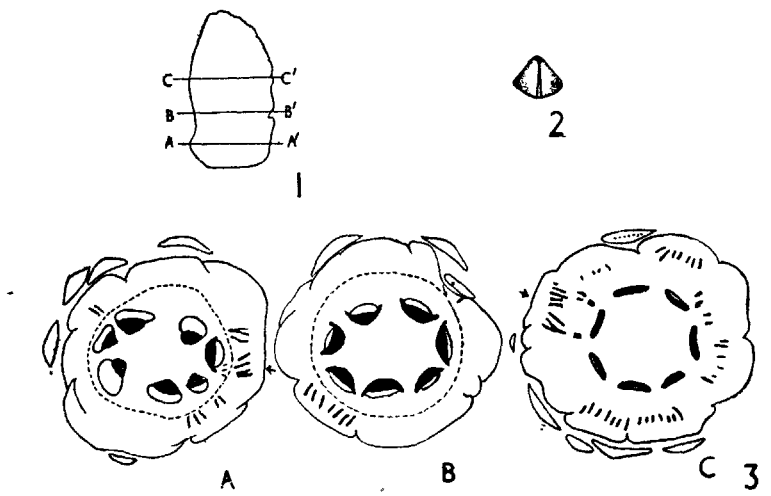
Description.

External appearance of the cone.—The figures 1 and 2 in Pl. V represent some ellipsoidal cones which measure about 2 cm. in length and 1·3 cm. in diameter. They appear to be sessile and are covered with crowded, imbricate, small scales which are spirally arranged. In passing around the middle part of the cones, 9–11 scales are met with. They look rhomboid but are really triangular in shape, because some part of the leaf base is covered by the two neighbouring scales. The scales are 3 mm. long and 3 mm. wide in average, and have a prominent median dorsal keel and an obtuse, slightly out-turned apex (text-fig. 2). Because of bad preservation most of apex of the scales have already been lost and only some rhomboid cushions of the leaf bases are left on the cone axis (Pl. V, fig. 1).

General Morphology and Anatomy of the Cones.—Pl. V, fig. 3, represents one of the longitudinal sections of the cone made from the one shown in Pl. V, fig. 1. The cone consists of a thick axis, covered by some small scales (*s*). In these sections the fertile organs are only represented by some disorganised tissues found in the two flanks, left and right of the tip of the cones in which hundreds of pollen grains (*p*) are enclosed. These pollen grains are grouped in masses and thus considered definitely belonging to the cone. Accompanied with these, a few elliptical bodies are present which are rather suggestive of pollen sacs. But due to bad preservation they are much crumbled and therefore no detailed description can be given. Under these elliptical bodies some tracheids have been found which may have supplied the male organs. Furthermore we carefully examined a series of transverse sections (text-figs. 3A–C) cut from the base to near the tip of the cone figured in Pl. V, fig. 2, and found no fertile organs elsewhere. Thus so far the present cones are concerned the microsporophylls may have arisen only from the terminal or subterminal region of the cones. As there is no indication of female organs in these cones, we may safely say that our cones most probably are unisexual.

Epidermal structure of the cone-scales.—Owing to bad preservation, we could not obtain any cuticle from the cone scales by maceration. However, examining the cone figured in Pl. V, fig. 1, under microscope, we found that the epidermis on the abaxial surface of the cone scales is composed of mainly 4–7 sided isodiametric cells, about 50–70 μ in diameter (text-figs. 9 and 10) which do not form any regular rows. The anticlinal walls of these cells are almost straight and become slightly thicker at the corners of the cells. No stomata have been observed.

Anatomy of the Cone-axis.—Text-figs. 3A–C represent the diagrams traced from photographs of three successive cross-sections cut between the base and the part just below the tip of the cone figured in Pl. V, fig. 2. The three approximate planes of the sections are indicated in text-fig. 1, by the lines AA′ BB′ and CC′. In these cross-sections a massive pith is seen which is surrounded by a ring of 7 vascular bundles, a thick cortex, and the bases of cone scales. A longitudinal section of the same is shown in Pl. V, fig. 3.



TEXT-FIG. 1. Diagram of the cone, shown in Pl. V, fig. 2. The lines AA′, BB′ and CC′ indicate the levels at which cross sections were made. (×1).

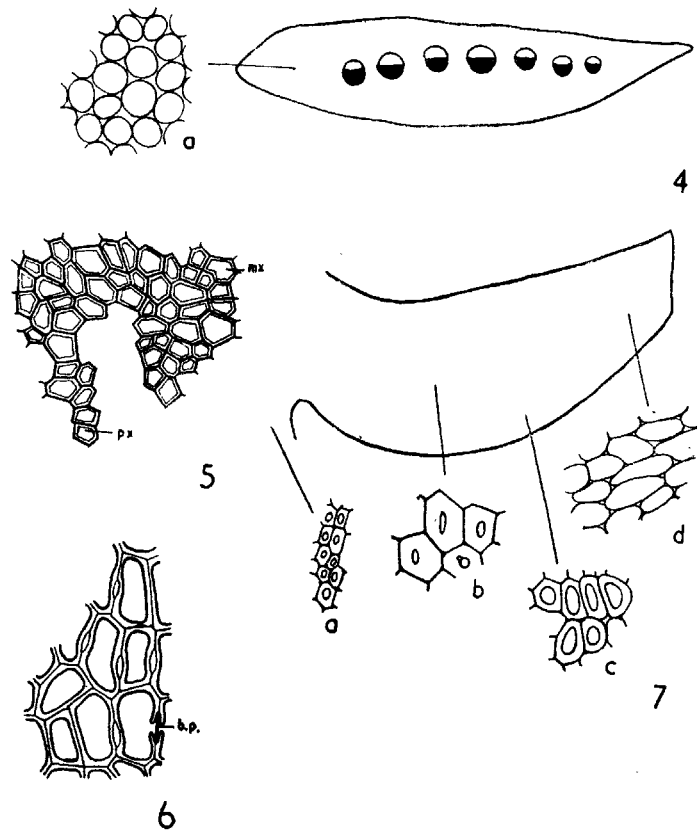
„ 2. Sketch of a cone scale, showing the out-turn apex and the median dorsal keel. (×2).

„ 3. Diagram traced from photographs representing vascular structure of cone axis as seen in a series of cross-sections A, B, and C from base to the level near the apex, indicated by lines AA′, BB′ and CC′ in text-figure 1. Origin and course of the vascular supply of some cone.

In structure the pith is quite uniform. It consists mainly of parenchymatous cells which are more or less isodiametric and 4–7 sided in cross-section and slightly elongated in longitudinal section (text-figs. 11 and 12). Neither resin canals nor secretory cells are seen. But occasionally in the peripheral region of the pith, near the scale bases, some small stone cells are observed (text-fig. 7*a*). These cells are grouped in vertical rows, about 10 or more cells in length and about 2-3 cells across, running parallel to the surface.

At the base of the cone the vascular strands are seven in number and triangular to elliptical in cross-sections. A few of them seem to have been united but now become separate from each other. They are collateral, with a considerable amount of xylem and phloem. Most of them are secondary in nature, intercalated with uniseriate ray cells. At this level the phloem forms a broad concave arc, with its two flanks almost touching, left or right, its neighbouring bundles. But in the section shown in text-fig. 3A cut at the level slightly above the base of the cone the

bundles look thicker and are arranged at a distance from one another. The tracheids of the secondary xylem (X^2), being densely arranged, are squarish in cross-section (Pl. VI, fig. 9). It appears that only the radial walls of the tracheids have developed uniseriate bordered pits (Pl. VI, fig. 11 and text-fig. 6) *b.p.* The longitudinal sections show that the tracheids of the bundles in this region are mainly pitted but some of them which are better preserved show both bordered pits (*b.p.*) and spiral bands (*s.b.*) (Pl. VI, fig. 12). At slightly higher level (text-fig. 3B) the



TEXT-FIG. 4. Diagram of cross section of a cone scale showing seven vascular bundles; 4a. Cross section of part of a cone scale showing cells of ground tissue. 4 (×25), 4a (×135).

„ 5. Cross section of a part of vascular strand shown in text-fig. 3C. *px*, protoxylem and *mx*, metaxylem. ×270.

„ 6. Cross section of a part of the secondary xylem shown in Pl. VI, fig. 11. *b.p.*, bordered pit. ×540.

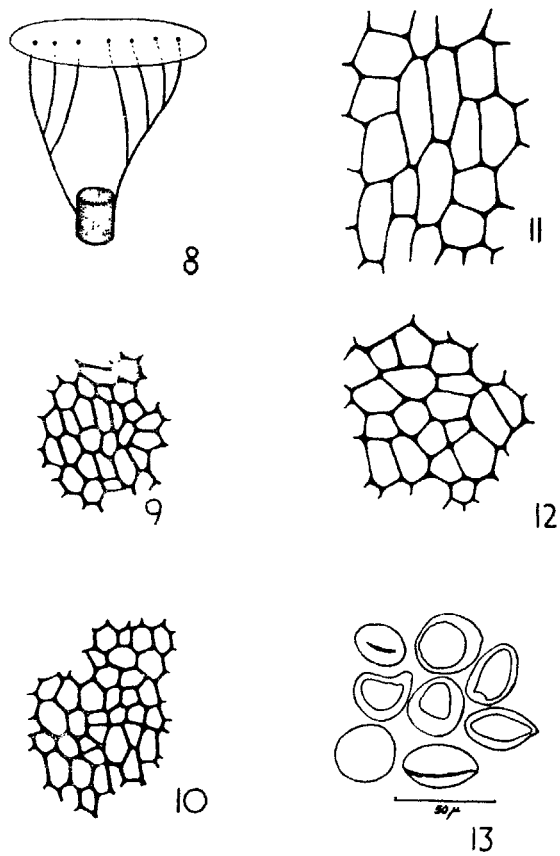
„ 7. Sketch of a cone scale in longitudinal section indicating the location of the following tissues:
(*a*) Group of small stone cells. (*b*) some large stone cells. (*c*) collenchymatous cells, and (*d*) cells of the ground tissue. ×135.

vascular bundles become elongate and in the section cut near the tip, vascular strands are transformed into thin arcs, with their concavity towards the outer surface (text-fig. 3C; Pl. VI, fig. 8). These bundles are primary in nature. As seen in longitudinal sections these bundles are composed of only spiral and finely scalariform tracheids which at some place, near the tip of the cones, disappear altogether. The bundles are collateral and endarch. A row of protoxylem group (*px*) is shown

in part in text-fig. 5 where there is no metaxylem (*mx*) developed on the centripetal side.

The phloem (Pl. VI, fig. 9, *ph*) is not well preserved but it is marked by some layers of heavy-walled elements alternating with thinner walled ones with regularity in the tangential direction.

Pericycle is not clearly seen in these specimens, but the cortex is well developed; it consists of small parenchymatous cells. In the inner cortex (*i.c.*) these cells are roundish in cross-section, with well-developed intercellular spaces (Pl. VI, fig. 8), while those in the outer cortex (*o.c.*) are rather densely arranged and squarish in cross-section (Pl. VI, fig. 7).



TEXT-FIG. 8. Diagram showing the origin and course of vascular supply of the cone scales.
„ 9 & 10. Outer epidermal cells of the terminal and the basal parts of a cone scale. ×60.
„ 11 & 12. Longitudinal and cross-sections of pith cells. ×135.
„ 13. Sections of pollen grains. ×270.

The cortical cells (*c.s.*) near the scale base (Pl. VI, fig. 7) are similar to those of the outer cortex, except that they are very much flattened.

In all specimens the epidermis is not well preserved.

Anatomy of Cone-scales.—The cone-scales are rather simple in structure. Two to three layers of hypodermal cells are visible under the epidermis (text-fig. 7*c*) but these cells are more developed at the margin of the scales. The mesophyll is composed mainly of round to ellipsoidal parenchymatous cells (text-figs. 4*a* and 7*d*) which show no clear differentiation into palisade and spongy tissues. At the base

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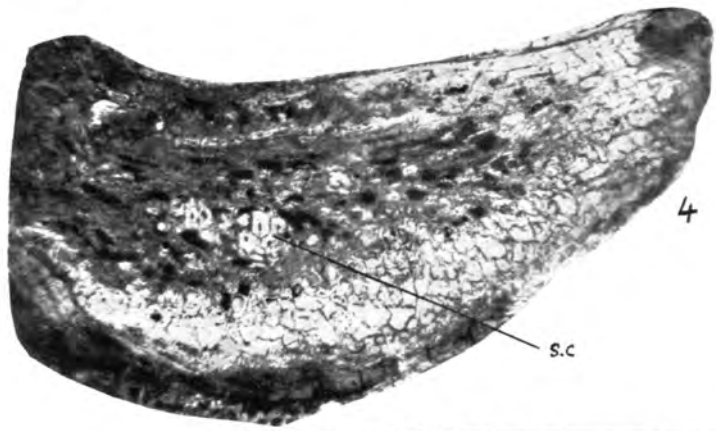

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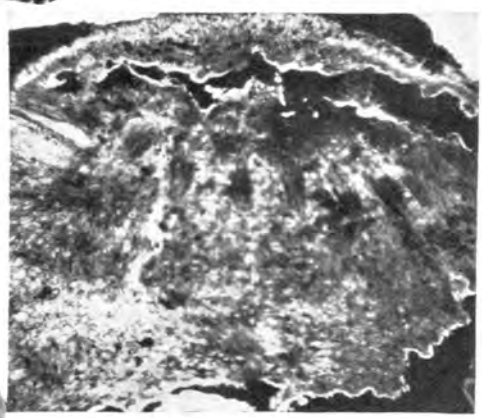

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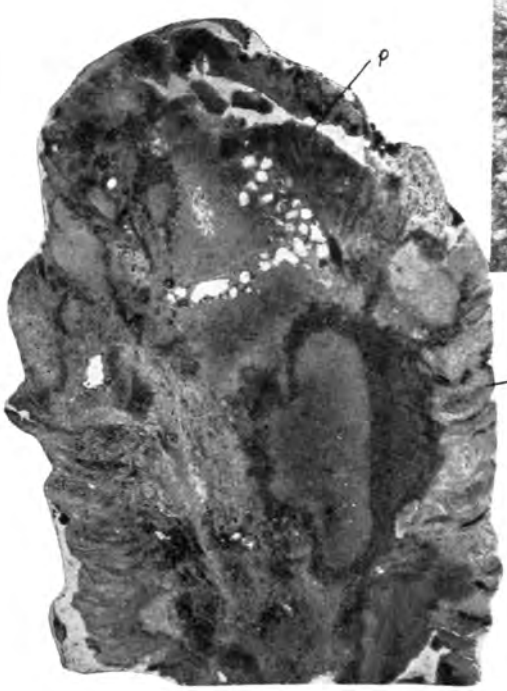

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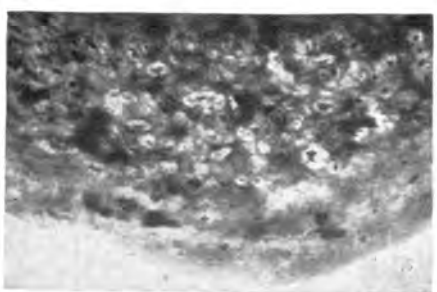

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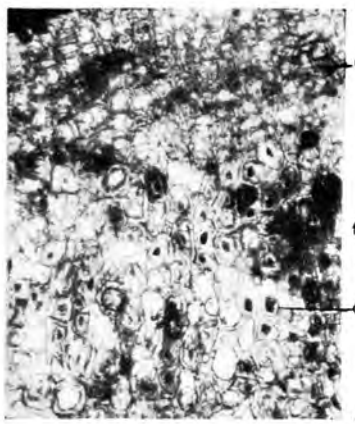

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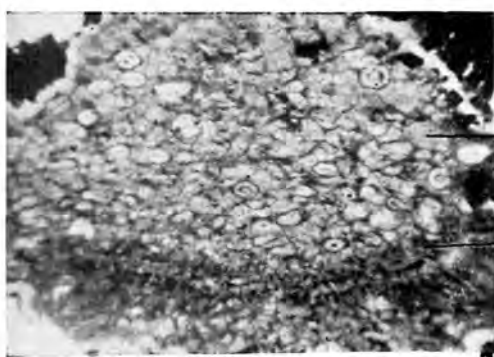

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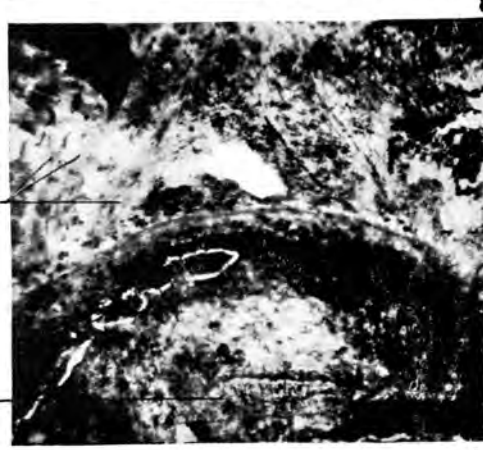

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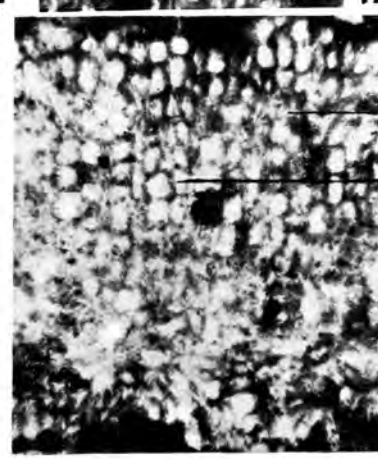

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of the scales, these cells are more densely arranged and squarish in cross-section, but higher up they become rather loose with well-developed intercellular spaces. Here and there a few stone cells (Pl. VI, fig. 4 and text-fig. 7*b*, *s.c.*) are found intercalated among the mesophyll cells. No resin canals are seen. These scales are somewhat fleshy in nature. The same structure is seen in the longitudinal sections. In Pl. VI, fig. 4, the ground tissue is unfortunately completely hidden by some cracks in the matrix which give a false impressions of pattern of cells.

The vascular bundles are parallel and about 7 in number at the base of the scales (text-fig. 4). These bundles also appear to be collateral and they are not enclosed by any kind of thick-walled cells. In longitudinal sections they show only spiral and finely scalariform tracheids. Pl. VI, fig. 5, shows a cross-section of a scale cut just above its middle region, where only ground tissue is seen, without any sign of vascular bundles.

Origin and course of the vascular bundles of the cone-scales.—The vascular bundles which supply the scales are given off from both the free ends of the bundles of the cone axis (Pl. VI, fig. 10; text-fig. 3A). Tracheids in these bundles are rather short. Their walls appear to have reticulate thickenings. As the preservation is not very satisfactory, it is very difficult to say whether these tracheids are really transfusion tissues of the type usually found in the same position on the two flanks of xylem strand in the scale leaves of some recent conifers such as *Juniperus*, etc. (Hsü, 1935).

The bundles first go outwards almost at a right angle to the cone axis and each soon divides into two small branches. As the branches pass outwards and upwards through the cortex, they lose their secondary tissues (Pl. VI, fig. 10) and divide once more to form seven (rarely eight) small bundles; three are found on one side, and four (occasionally five) come from the other, as in the parts indicated by an arrow in the text-figs. 3A, 3C. They run parallel to one another into the scale and are dying out when they travel about half the distance of whole length in it.

Pollen grains.—The pollen grains are very small, round to ellipsoidal about 30 μ in diameter, or 30×35 μ to 25×40 μ, with thick and smooth wall (text-fig. 13). Neither a slit, nor a wing is seen in a pollen grain. Some of them have elongated or irregular folds which are due to preservation.

Comparison, Discussion and Conclusion.

Cones of this type have once been recorded in India from the Jurassic of Vemavaram of the Kota stage by Professor Sahni (1928, p. 37; Pl. VI, fig. 80) who named them *Conites*. These fossils are preserved only as casts, but look very much like ours in their external appearance. Therefore it is likely that they are identical. When we compare our cones with the leafy shoots of *Brachyphyllum* collected by one of us (Bose) from the same bed, we find that the form and arrangement of the rhomboid scales in our cones also have a very great resemblance to those of the leafy shoots of *Brachyphyllum* sp. The description of these shoots is going to be published separately by Bose. Each of these scales have a prominent median dorsal keel and an obtuse out-turned apex just like those of the leafy shoots. The cells of the epidermis of the abaxial surface of the cone scales also show a close resemblance to those of the epidermis of the same surface of the scale leaves. But the difference is that the epidermal cells of the present specimens are slightly bigger in size, otherwise they are almost identical.

In comparing their internal structure, the pith and the cortex of both the cone axis and of the stem are composed mainly of parenchymatous cells, except that some stone cells are present in the outer region of the pith of the cone axis only. In general, the cone axis shows less development of secondary xylem than that of the stem. In both cases the secondary wood is compact with small tracheids and uniseriate rays and only on the radial walls of the tracheids, uniseriate bordered pits

are developed. The spiral bands found on the walls of the secondary tracheids of the present cones are again very much similar to those of the stem of *Brachyphyllum* sp. Therefore the present cones probably belong to a species of *Brachyphyllum*.

We have already mentioned that except some groups of small pollen grains found in the terminal region of the cones, no fertile organs have so far been observed. This fact indicates that the microsporophylls may have only arisen at the terminal or sub-terminal region of the cones. If so, it would recall those of the male cones of the modern *Taxus* (Zimmermann, 1930, p. 232, fig. 160A).

Unfortunately our investigation is limited due to lack of sufficient specimens. Though we know the importance of the location of microsporophylls in the male cones of conifers, yet it is no use to discuss this problem without sufficient facts regarding these cones in front of us.

Furthermore, Miss Kendall (1949, pp. 160-1; fig. 4A–E) described some male cones of *B. mamillare* Brongn. from the Middle Jurassic of Yorkshire. In her figure 3C, she showed some microsporophyll stalks arising from the middle part of the cones, and in her figure 3B, a part of the cuticle obtained from the tip of one of these microsporophylls has been given. If so, the microsporophylls can also arise from the middle region of the cones of *Brachyphyllum*.

In comparing the pollen grains of our cones with those of *Brachyphyllum mamillare* described by Kendall (1949, p. 161), they are quite similar, except that ours are variable in form and not always round. In size, the pollen grains of *B. mamillare* are 60–80 μ in diameter, while ours are about 30 μ.

So far the occurrence of spiral bands on the walls of secondary tracheids is concerned, our cones share the character with the modern *Taxus*.

Miss Kendall (1949) thinks that *Brachyphyllum mamillare* Brong. is a member of the Araucariaceae, but in our opinion as a whole *Brachyphyllum* may be still considered as a form genus. Since we have been able to obtain some information about it through the Indian fossils. we may expect a better result if further investigations are carried out.

Abstract

This paper describes some coniferous male cones collected from Amarjola in the Amrapara district, Bihar. These cones are ellipsoidal in form, covered by crowded, imbricate, small, rhomboid, spirally arranged scales. Each of them has a prominent median dorsal keel.

The outer epidermis of the cone-scales is composed mainly of isodiametric cells which do not form any regular rows.

The cone axis possesses a large pith, surrounded by a ring of seven vascular bundles and a thick cortex. The cells of pith are mainly parenchymatous. The vascular bundles are collateral and endarch, with secondary tracheids having both bordered pits and spiral bands.

The main part of the scales is composed of ground tissue. Therefore it appears fleshy in nature. Under the epidermis 2-3 layers of hypodermal cells and at the base of the scales, seven parallel vascular strands are seen. These strands arise from free ends of the bundles of the stele, but divide rapidly into seven small bundles passing into the scales and die out when they travel about half the length in the scales.

Pollen grains are small, round or ellipsoidal and are found in groups only at the terminal region of the cones enclosed by some disorganised tissues of probably microsporangia and microsporophylls.

Comparing the external morphology of the cones, the outer epidermal characters of the cone scales and the internal structure of the cones, with those of the leafy shoots of *Brachyphyllum* which are found in the same locality, it appears that these cones belong most probably to the same genus.

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Explanation of Plates.

Plate V.

Fig. 1. A cone. (×·8.)
,, 2. Another cone. (×·8.)
,, 3. Longitudinal section of the cone, shown in fig. 1, *s*, cone scale; *p*, pollen grains. (×5·6.)
,, 4. Longitudinal section of a cone scale; *s.c.*, stone cells. (×51.)
,, 5. Cross-section of a cone scale cut just at the level above its middle region. (×51.)
,, 6. Cross-section of the outer part of a cone near the scale base, showing seven vascular bundles running from the cone axis into a cone scale. (×21.)

Plate VI.

Fig. 7. Cross-section of the outer cortical region of a cone. *o.c.*, outer cortex; *c.s.* cortical cells near the scale base. (×108.)
,, 8. Cross-section of part of the central region of the cone, made at the level CC′, indicated in text-fig. 1, showing vascular bundles (*v.b.*) containing only primary tissues; *i.c.*, inner cortex. (×49.)
,, 9. Cross-section of part of the central region of the cone made at the level BB′ indicated in text-fig. 1, showing secondary xylem (X^2) and phloem (*ph*) of the vascular bundles. (×45.)
,, 10. Cross-section of part of the central region of the cone made at the level AA′, indicated in text-fig. 1, showing the course of scale traces (*s.t.*). (×20.)
,, 11. Cross-section of basal part of a cone, showing the tracheids of the secondary xylem (X^2) with bordered pits (*b.p.*) developed on their radial walls. (×207.)
,, 12. Longitudinal section of the basal part of a cone, showing secondary tracheids of the vascular bundles, having both spiral bands (*s.b.*) and bordered pits (*b.p.*) developed on their radial walls. (×497.)

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