ON SOME MALE FRUCTIFICATIONS REFERABLE TO *GLOSSOPTERIS* AND THE SYSTEMATIC POSITION OF THE GENUS

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INTRODUCTION

The record of any undoubted fructification of *Glossopteris* has long been missing. The recent valuable contribution by Plumstead (1952) to the female fructifications of the genus has considerably added to our knowledge regarding its affinities. Since then, a few other Glossopterid female fructifications have also been described by the present author (Sen, 1954, unpub.). The morphological interpretation of these organs, however, remain controversial (Edwards, 1952; Walton, 1952; Plumstead, 1952; Sen, unpub.). It has been felt that the discovery of male organs of *Glossopteris* is now likely to settle its systematic position perhaps more conclusively. Fortunately such a possibility is now at hand.

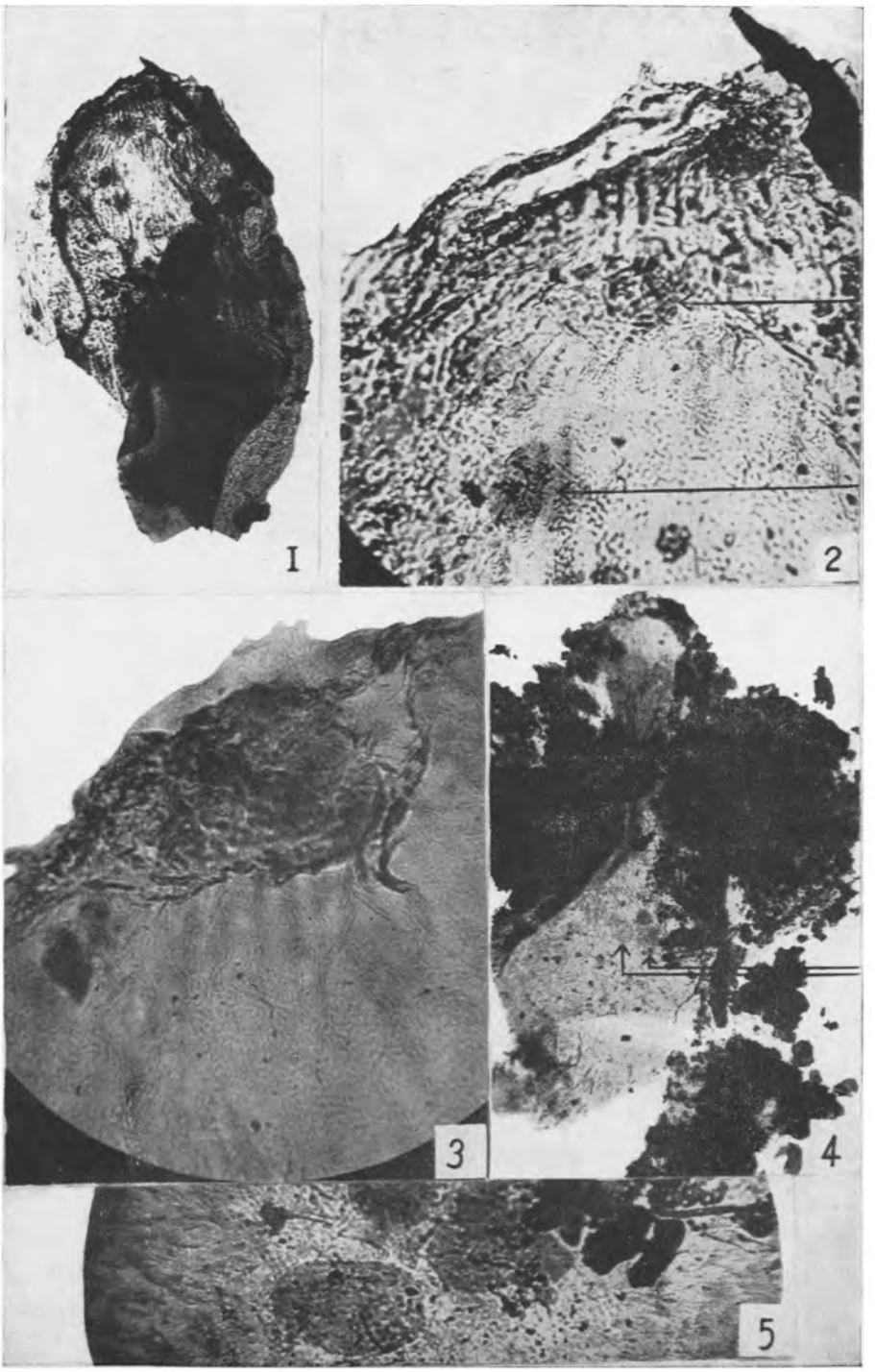
Recently a number of sacs containing typical *Pityosporites* type of pollen have been recovered from Indian Lower Gondwana coal. Since *Pityosporites* has been assumed to be the pollen of *Glossopteris* on grounds of their close association in the Lower Gondwana rocks in different parts of the southern hemisphere and particularly India (Virkki, 1945; Ghosh and Sen, 1948; Sen, 1948, 1953), it was thought that intense search for these sporangia-like structures (referable to *Glossopteris*) might be profitably pursued. Such a successful finding is also likely to add more definite clues to the long standing problem of the botanical affinities of *Glossopteris*.

A large number of analyses of Indian Lower Gondwana coals from the Raniganj and Karharbari stages by the present author yielded a variety of sporangia-like structures, some of which have been found associated with or containing typical two-winged pollen of *Pityosporites* type (plates VII and VIII, figs. 1–5 and 6). When smeared under a cover glass, some of them liberated numerous *Pityosporites* type of pollen grains (plate VIII, fig. 11). These structures containing *Pityosporites* are as such probably related to *Glossopteris*. The pollen masses may also be teased out from pollen sacs (plate VIII, figs. 9-10), or they may occur freely in the maceration residues (plate VIII, fig. 8).

DESCRIPTION OF THE MICROSPORANGIA

The microsporangia are variable (probably belonging to different species) (plates VII and VIII, figs. 1–4 and 6), sac-like structures of peculiar form often looking like moss capsules. They occur freely and singly (possibly not otherwise obtainable in maceration), and taken as such they are unlike the sori of ferns. They appear to be sessile, somewhat elliptical, tapering at one extremity, the other end (possibly the attachment region) usually remaining relatively broad; often they look almost oval. They measure 800 μ–1,500 $\mu \times 650$ μ–1,000 μ.

The sporangia are unilocular, dehiscing regularly more or less in transverse plane at the apical region (plates VII and VIII, figs. 1–4 and 6), but the subsequent tendency for dehiscence in a longitudinal direction is also sometimes evident (plates VII and VIII, figs. 4 and 6); all the sporangia appear exannulate. The cells of the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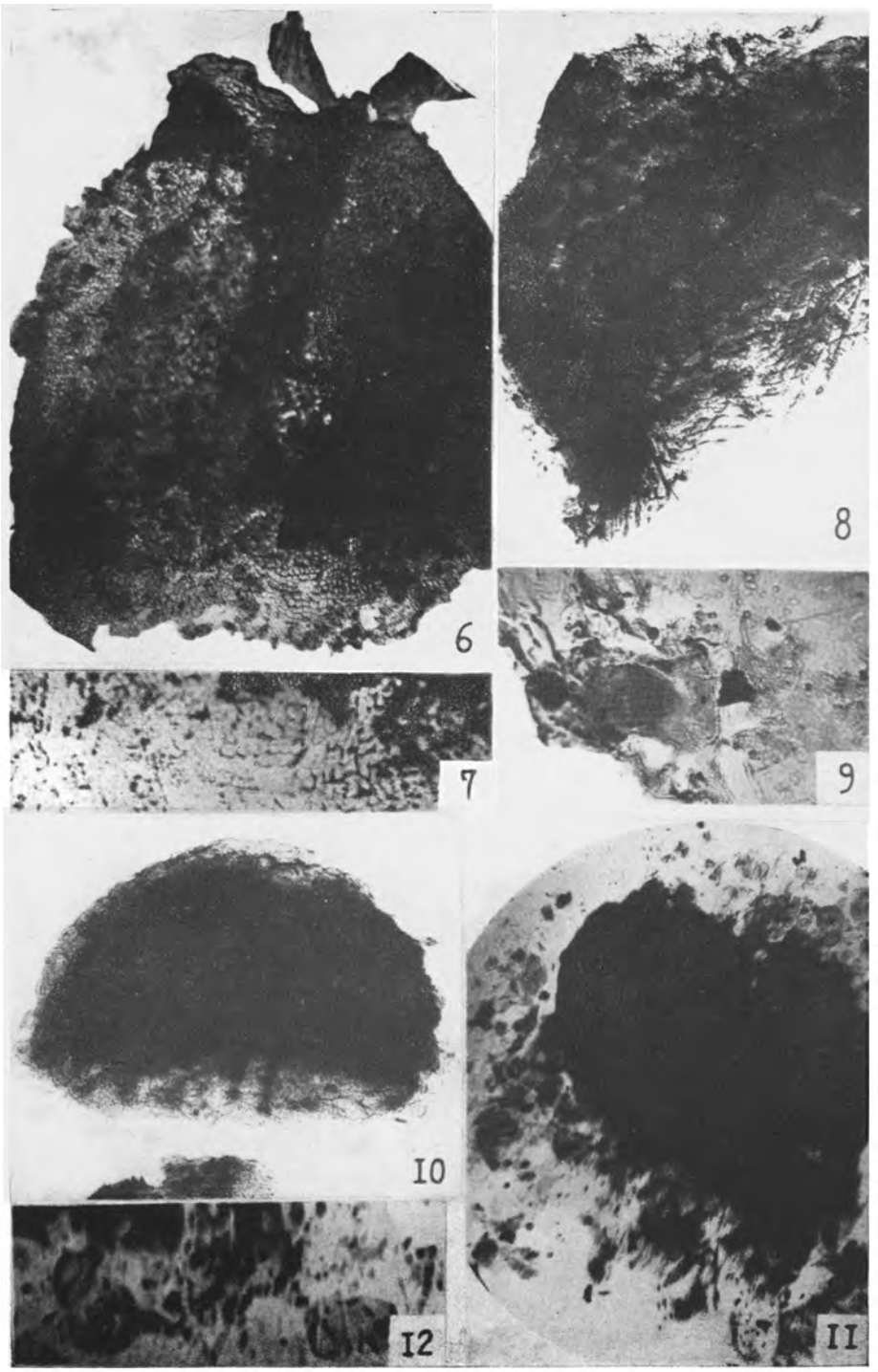
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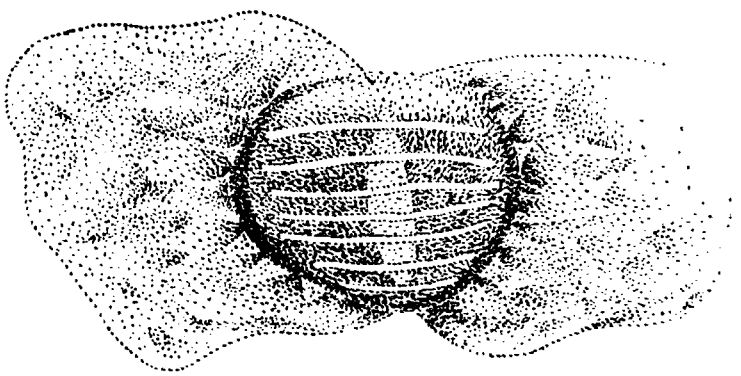
sporangia wall are usually long, regularly and/or irregularly rectangular to rhombic shaped, sometimes small and almost squarish to rectangular (plates VII and VIII, figs. 2-3 and 6-7), more often their outlines are destroyed. It has been found that small masses of *Pityosporites* are sometimes covered by torn pieces of tissues consisting of small squarish to rectangular cells (plate VIII, fig. 8) which are similar to the cells of a sporangium (plate VIII, fig. 6). The sporangial wall is usually very thin possibly due to the effects of maceration and as such hardly measures more than 1·5 μ in thickness.

The pollen grains are bilateral with two reticulately marked characteristic bladders placed on opposite sides of the body which is surrounded by a thick rim (Text-fig. 1; plates VII and VIII, figs. 2, 5, 9 and 11-12). When the pollen grains occur in clusters or within the sacs they are probably not fully mature since their size is usually relatively smaller than those found free. The types of grain observed in masses and/or within the sacs range in total length (bladder tip to bladder tip) from 50 μ to 100 μ. The description of *Pityosporites* types of pollen, as above, is very common in palynological literature of the Palaeozoic (Schopf, Wilson and Bentall, 1944; Virkki, 1945; Ghosh and Sen, 1948; Sen, 1948; and others).



TEXT-FIG. 1. *Pityosporites* sp. A characteristic pollen inside the sac as shown in the Plate VII, fig. 2. ×862.

PREVIOUS RECORDS OF MICROSPORANGIA REFERRED TO *GLOSSOPTERIS*

The microsporangia long known to be referable to *Glossopteris* are some empty and exannulate bodies reported by Arber as far back as in 1905. These so-called microsporangia occur in groups, and are probably borne on the lower concave surface of some transitional structures between scale and foliage leaves found in association with *Glossopteris browniana*. Arber compared his sporangia with those of a recent cycad, and that described by Zeiller as *Discopteris Ralli*. He also referred to the earlier suspicions regarding the presence of sori-like bodies found associated with *Glossopteris*. In this connection Feistmantel's (1881, 1882, 1886) reference to the sori or like bodies, which are variously arranged on the margin or surface of some species of *Glossopteris*, deserves special consideration. Unfortunately Feistmantel's descriptions are very brief and his illustrations are not in sufficient detail so that they can be profitably compared with the present findings.

Subsequently in 1932, Du Toit described *Eretmonia natalensis* which might be the organ bearing the types of microsporangia already referred to by Arber (1905) and also described by Seward (1907). Du Toit interpreted that his find was most probably the male reproductive organ of a species of *Glossopteris*.

Seward and Sahni's (1920) reinterpretation of *Ottokaria bengalensis* suggested that this specimen was probably the ovulate organ belonging to a pteridosperm. But Plumstead (1952) does not altogether rule out the possibility of the species being the staminate reproductive organ of a *Glossopteris*, which view is, however, not at all suggestive because *Ottokaria bengalensis* appears more as 'a cupular investment of a seed'.

In 1947 Teixeira illustrated a leaf of *Glossopteris indica* with two rows of projections, 'regularly arranged, alternate, recalling the sori of certain ferns'. A fragment of a leaf of *G. angustifolia* showing similar structures had earlier been described by Zeiller (1896). Apparently these structures cannot be closely compared to the microsporangia described in this paper.

Discussion

Whenever a Lower Gondwana coal or shale (bearing *Glossopteris*) has been analysed, *Pityosporites* usually appears to be the constant and often the dominating feature of the microfloral yield, like the species of *Glossopteris* in the coal-bearing Permian and U. Carboniferous flora of the southern hemisphere (Virkki, 1945; Ghosh and Sen, 1948; Sen, 1948, 1953). The close association of *Pityosporites* with *Glossopteris* has more clearly been manifested in the eastern part of the Raniganj coalfield (Ghosh and Sen, 1948). In this field the number and types of *Pityosporites* gradually decline in successively higher beds, i.e., in seams nearer Panchet where *Glossopteris* is also on the decline. The Raniganj coal measure is characterized by about 10 species of *Glossopteris* whereas in Panchet there are only 4 species. Hence there are fewer number and types of *Pityosporites* in the upper portion of the coal measure where *Glossopteris* is fast vanishing. Virkki (1945) also obtained a few *Pityosporites* adhering to small pieces of cuticle of *Glossopteris browniana* from a macerated piece of shale from the Permo-Carboniferous rocks of Newcastle, New South Wales. It may not be very wise to underrate such a close association of *Pityosporites* and *Glossopteris* existing over a great length of time and spread over an extensive area. If *Pityosporites* is finally accepted as pollen of *Glossopteris*, it is logical to conclude that the structures bearing *Pityosporites* are microsporangia of *Glossopteris*.

Schopf *et al.* (1944) hold that there can be little question that the grains of the *Pityosporites* type are referable to coniferae. At the same time they recognized the diversities of forms among the *Pityosporites* which according to them possibly contain elements of separate families. A step to segregate such an artificial and heterogeneous genus into more natural units has recently been taken up (Kosanke, 1950).

It is definite that all spores so long recognized as *Pityosporites* do not belong to the same close circle of affinity, and as such most of the species of *Pityosporites* reported from the *Glossopteris* bearing Lower Gondwana rocks of the southern hemisphere are at least different from those occurring elsewhere. Moreover, the coniferous affinity of *Pityosporites* is solely based on theoretical assumption. Under the circumstances the sporangia containing typical Gondwana *Pityosporites* appear to be referable to *Glossopteris* despite the former's hypothetical relationship to the conifers. The short account on the botanical affinities of the *Glossopteris* that follows is based on this assumption.

Glossopteris fronds are often found in association with small seeds (Walton, 1940) and *Vertebraria* stem possessing secondary wood with multiseriate bordered pitted tracheids and parenchymatous medullary rays of gymnospermous type (Walton and Wilson, 1932). However, it is now known that most probably *Glossopteris* and *Vertebraria* are not parts of the same plant (Thomas, 1952*a*). But on the basis of extraordinary types of ovulate organs recently found attached to some species of *Glossopteris* (Plumstead, 1952) 'it may be regarded as a pteridosperm,

if that term is used in a very broad sense; but it differs from all the known plants of this type in both vegetative and reproductive characters' (Thomas, 1952*b*). Professor Harris (1952) has also doubted the propriety of including such plants under pteridosperms. He has further felt that Plumstead's (1952) interpretation of the ovulate organ of *Lanceolatus* type would suggest this plant to be an angiosperm.

The simple unilocular sporangia containing *Pityosporites*, as described in this paper, appear to be akin to those of the primitive gymnosperms. The pollen of these sporangia, i.e., *Pityosporites*, superficially resembles that of abietineae as suggested by Schopf *et al.* (1944), but the chances of *Glossopteris* being leaves of a conifer appears to be a remote possibility. Moreover, the pollen sacs, as found by the author, are not at all abietinean.

It is apparent that an assemblage of detached organs consisting of *Glossopteris* fronds, simple microsporangia described in this note, and cupular organs protecting the seeds, which are found attached to *Glossopteris* by Plumstead (1952), point more to a pteridospermous nature than to any other group of plant. Some suggestions and reinterpretation of the morphology of ovulate organs have since been made to settle the systematic position of the genus (Edwards, 1952; Walton, 1952; Sen, unpub.).

Summary

The pollen sacs of *Pityosporites* type of pollen have been described from Indian Lower Gondwana coal. On grounds of very close association throughout the Lower Gondwanas *Pityosporites* has long been thought to be the pollen of *Glossopteris* and therefore, the sac-like structures containing this type of pollen may belong to *Glossopteris*. There has so far been no indubitable record of the male organs of this plant.

This new report has added some interesting generalizations to the existing assumption as to the affinities of *Glossopteris*.

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Explanation of Plates VII and VIII

Microsporangia containing or associated with *Pityosporites* sp.

Fig. 1. A sporangium containing a few *Pityosporites* type of pollen (shown by arrow heads). Note the regular nature of apical dehiscence. ×70.

,, 2. The enlarged view of the apical portion of the fig. 1. Note the typical *Pityosporites* type of pollen inside the sporangium and the nature of its cell wall. ×280.

,, 3. The enlarged view of the apical portion of a sporangium. Note the juxtaposed *Pityosporites* type of pollen grains near the dehisced mouth (forming a black mass) of the sporangium, and the disorganized nature of its wall cells. ×280.

,, 4. A sporangium containing some *Pityosporites* type of pollen (shown by arrow heads). ×50. Note the nature of longitudinal dehiscence of the sporangium which appears to be of subsequent development leading to collapse after apical dehiscence.

,, 5. The enlarged view of a portion of the inner surface of the fig. 4 showing *Pityosporites* type of pollen and faintly visible cell wall outlines. ×250.

,, 6. A sporangium with characteristic apical dehiscence and a subsequent tendency for dehiscing in longitudinal direction. ×52. Note the shapes of the cells at the base of the sporangium and compare with those in the figure 6.

,, 7. The enlarged view of the basal portion of the fig. 6 showing the nature of wall cells. ×110. Compare fig. 8.

,, 8. An irregularly torn compact mass of *Pityosporites* type of pollen under a cellular covering. ×65. Since it is a sub-spherical structure it has not been possible to photograph both the covering and the distinguishable pollen at the edges of the mass. Note the shapes of the cells of this covering tissue and compare with those at the base of the sporangium in the fig. 6 and also those in the fig. 7.

,, 9. A typical *Pityosporites* type of pollen somewhat isolated from the tissue matrix. ×215.

,, 10. A compact mass of *Pityosporites* type of pollen teased out of a sac-like body. ×70.

,, 11. A smeared semi-carbonized sporangium showing scattered pollen of *Pityosporites* type. ×60.

,, 12. The enlarged view of a portion of the fig. 11 showing typical *Pityosporites* type of pollen grains. ×165.

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