INTRASPECIFIC VARIATION IN *STRIATITES* SPORES*

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ABSTRACT

Undispersed spores from sporangia of *Arberiella* were isolated to study variations in their form caused by compression and maceration in order to assess the systematic importance of such variations in the demarcation of species of *Sporae dispersae*. The effect of maceration was also studied in spores of two living conifers *Pinus roxburghii* and *Cedrus deodara*. A new species of *Arberiella*, viz., *A. thomasii* is described.

INTRODUCTION

ALTHOUGH a large number of sporomorphs have been described from the Lower Gondwanas of India, yet the range of size and form within an individual species of these sporomorphs is often determined arbitrarily on the basis of dispersed spores. It was, therefore, thought that a better method of determining the range within any species could be based on the study of the variations inside undehisced sporangia which contained a particular sporomorph. Accordingly, we decided to investigate the range of size and form in *Striatites* type of spores which are known to occur in undehisced sporangia of *Arberiella* (Pant, 1958 and Pant & Nautiyal, 1960). Other reasons for selecting the sporangia of *Arberiella* for the present investigation are their common occurrence in the Lower Gondwana rocks and the diverse aspects in which their spores are compressed.

MATERIAL AND METHODS

The material used in the present investigation consists of coaly shales collected from the Raniganj coalfield. They are referable to the Raniganj Stage. Some pieces of shale were treated with hydrofluoric acid and the residue was washed in water. Sporangia of *Arberiella* were now sorted out of the residue and treated with Shulze's fluid. Other pieces of the shale were directly macerated in Shulze's fluid, and sporangia were again picked out of the residue. Chemical effects of maceration were noted by varying the duration of treatment with nitric acid and alkali.

For the sake of comparison, pollen grains of *Pinus roxburghii* and *Cedrus deodara* were subjected to chemical treatment similar to those of the fossils but it was not possible to imitate the changes which the pollen grains of *Arberiella* must have undergone during fossilization.

OBSERVATION

Sporangia

The genus *Arberiella* was originally made for compressed unilocular and stalked sporangia (Pant & Nautiyal, 1960). The sporangia may occur isolated or in groups

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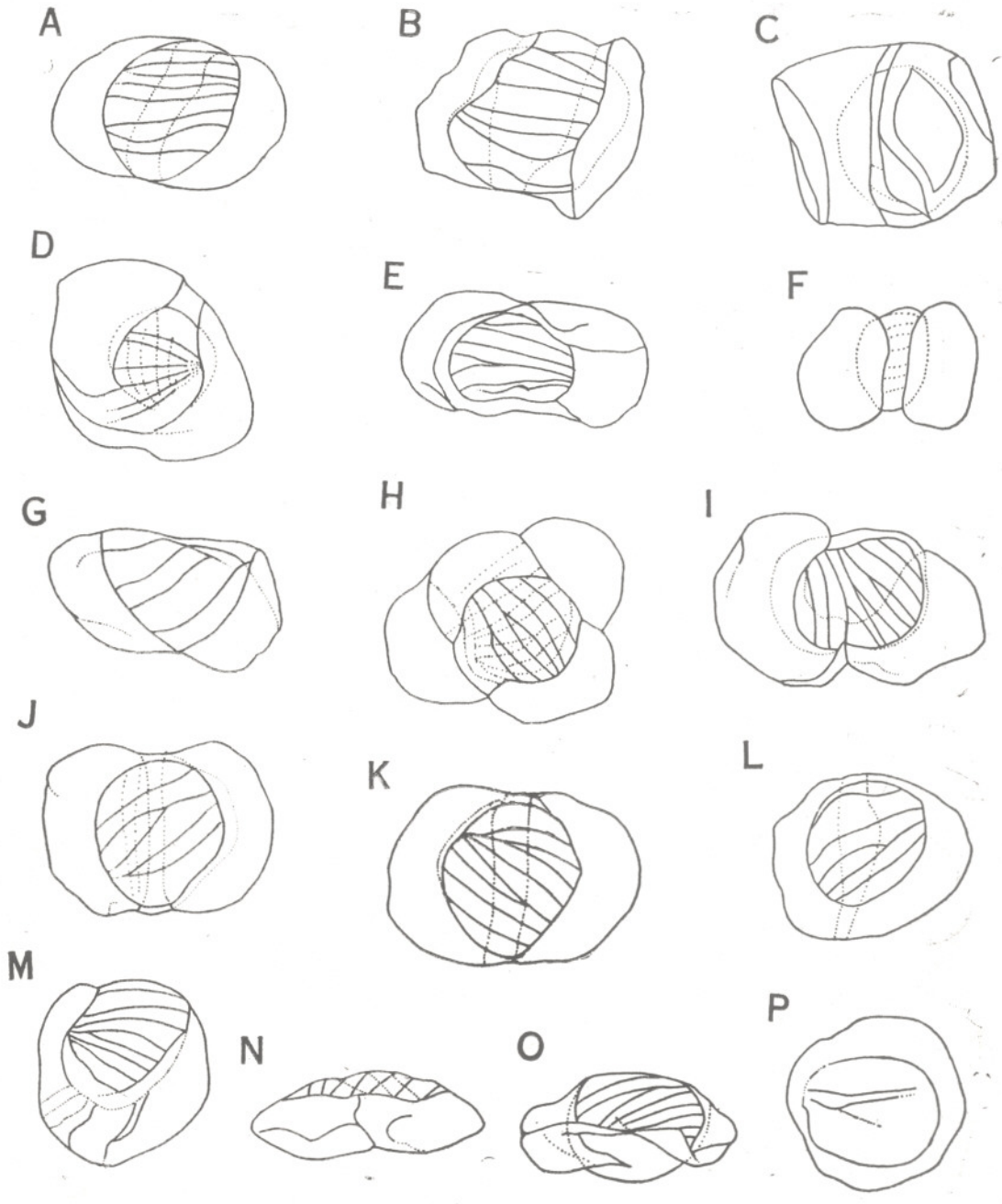
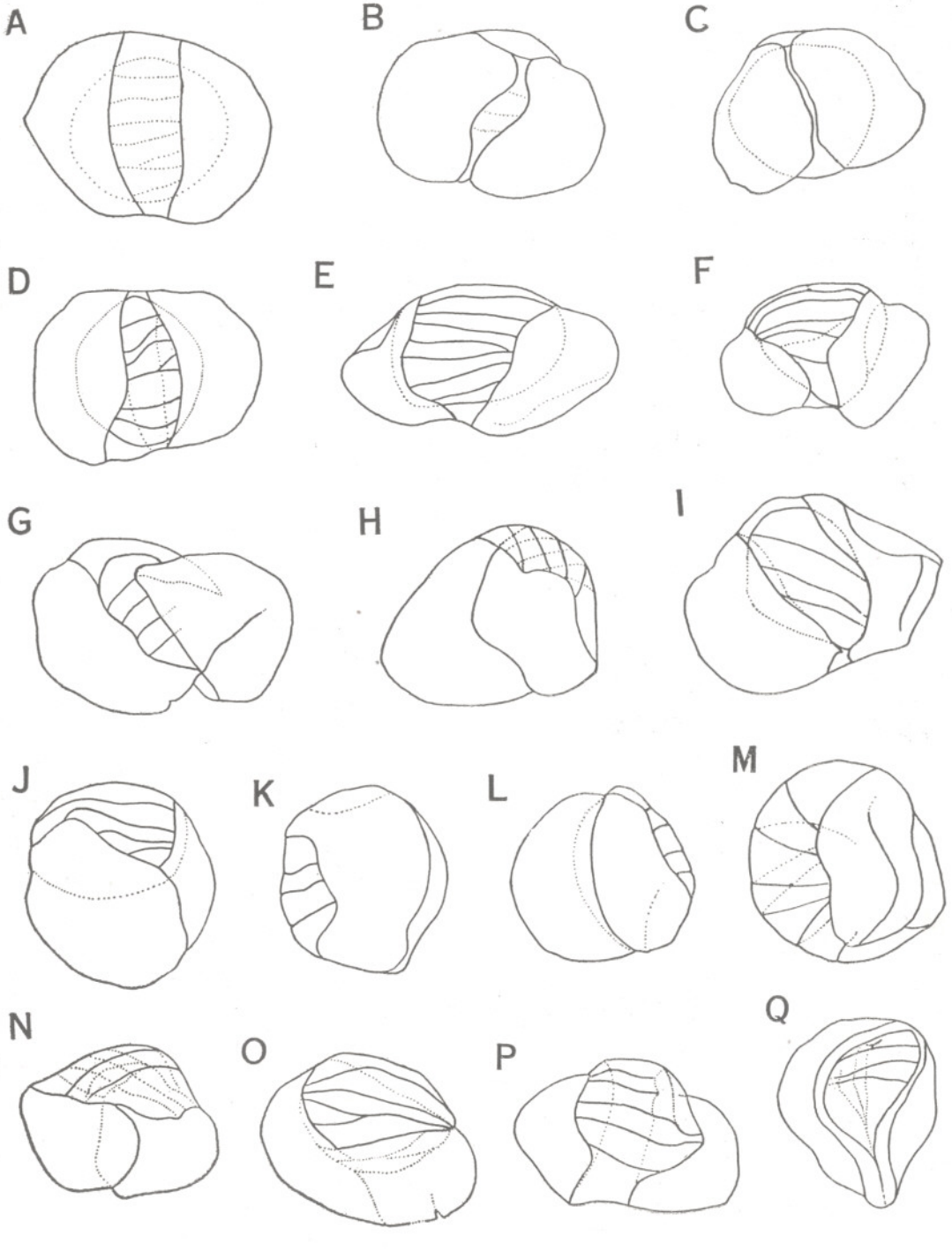
TEXT-FIG. 1 — *Arberiella vulgaris*. A — Dorsiventrally compressed spore with dorsal side up. Sl. No. 24; B and C — Dorsiventrally compressed spores with laterally folded and crumpled wings. Sl. No. 24; D — Spore showing two sets of criss-crossed striations. Sl. No. 24 (see plate 2, Fig. 5 also); E — Dorsiventrally compressed spore with some amount of anterioposterior compression. Sl. No. 24; F — Dorsiventrally compressed spore with the ventral side up. Sl. No. 24; G — Compression of a laterally twisted spore. Sl. No. 21; H — *Distriatites* type of spore showing criss-crossed striations and three wings apparently formed by adhesion of two compressed spores. Sl. No. 38 (see plate 2, Fig. 6 also); I, J, K, and L — Dorsiventrally compressed spores showing oblique striations formed by slight torsion of the corpus (see plate 2, Figs. 1-4 also); M — Dorsiventrally compressed spore with both wings partially compressed laterally and deflexed in anterior or posterior direction. Dotted lines over the wing depict imprints of striations. On the left is the margin of one of the wings and another line towards its right is a fold. Sl. No. 38; N — Anterioposteriorly folded spore with some amount of lateral compression. Sl. No. 38; O — Anterioposteriorly compressed spore with crumpled sacci, Sl. No. 38; P — Mechanically separated wing appearing as a spore. Sl. No. 20 (see plate 3, Fig. 5). All × 500.



TEXT-FIG. 1



TEXT-FIG. 2

where they are borne terminally on branches of slender stalks. The surface cells of sporangial wall are elongated and their dehiscence is longitudinal. Undehisced sporangia contain spores of *Striatites* type. Pant & Nautiyal (1960) have reported two species of *Arberiella* viz. *A. vulgaris*, from Raniganj coalfield, India and *A. africana* from Mhukuru Coalfield, Africa. The two species are based on spore size which is 40-55 μ×25-30 μ in *A. africana* and 50-85 μ×30-55 μ in *A. vulgaris*. During the present investigation we extracted not only typical sporangia referable to *A. vulgaris* (Plate 1, Figs. 1, 2) but sporangium-shaped masses of *Striatites* type of spores of distinctly larger size. These masses lack a surrounding jacket. We assume that their sporangial wall was rather delicate and it was either destroyed during fossilization or on the assumption that their wall dissolved in Schulze's fluid since these were obtained only in bulk maceration residues of the shale. We are unable to think of any other reason for the absence of the surrounding sporangial jacket and it is difficult to imagine that dispersed spores of *Arberiella* type could once again cluster into compact masses of the same shape as the sporangia of *Arberiella*. These spore clusters are, therefore, assigned to a third species of *Arberiella*, viz., *A. thomasii*. The spore clusters are thick and dark brown in colour and they gradually become thinner towards the margin where the outlines of some spores, compressed in different planes, can be seen.

Spore

The spores of *A. vulgaris* were taken out of undehisced sporangia. The other kind of spores were separated from sporangium shaped clusters herein referred to *A. thomasii*. Both kinds of spores are of *Striatites* type, having a corpus with parallel striations and two lateral sacci. All the spores are invariably compressed and we can recognize the following main forms among them:

1. Spores showing a circular strongly striated body with the two wings attached laterally in para position. A relatively wider portion of the striate body is exposed (Text-fig. 1 — A, B, D, E, H-M; Text-fig. 2 — D, G, I, L). We regard all these spores as compressed mainly in or almost in the dorsiventral plane with the dorsal side upwards (Text-fig. 3-B).

2. Spores with striated central body showing more or less asymmetrically tilted lateral wings. The side of the body towards which the wings are tilted, as a rule, does not show any striations (Text-fig. 1 — N, O; Text-fig. 2 — E, F, N-Q). These spores are presumably compressed more or less nearly in the anterioposterior plane (Text-fig. 3E).

3. Spores whose wings are separated by a narrow nonstriated intervening portion of the body. Fine focusing shows that the wings overlap the body and striations can sometimes be seen at a lower focus (Text-fig. 1 — C, F; Text-fig. 2 — A, B, C). We believe that these spores are compressed in the dorsiventral plane similar to those of type (1) but with the opposite (ventral) side upwards (Text-fig. 3C).

4. Spores exposing only a small portion of the body and the wings partly or completely overlap each other (Text-fig. 1 — G; Text-fig. 2 — H, J, K, L, M). These are regarded as more or less laterally compressed spores (Text-fig. 3-D).

There are numerous other types of spores which present combinations or distorted

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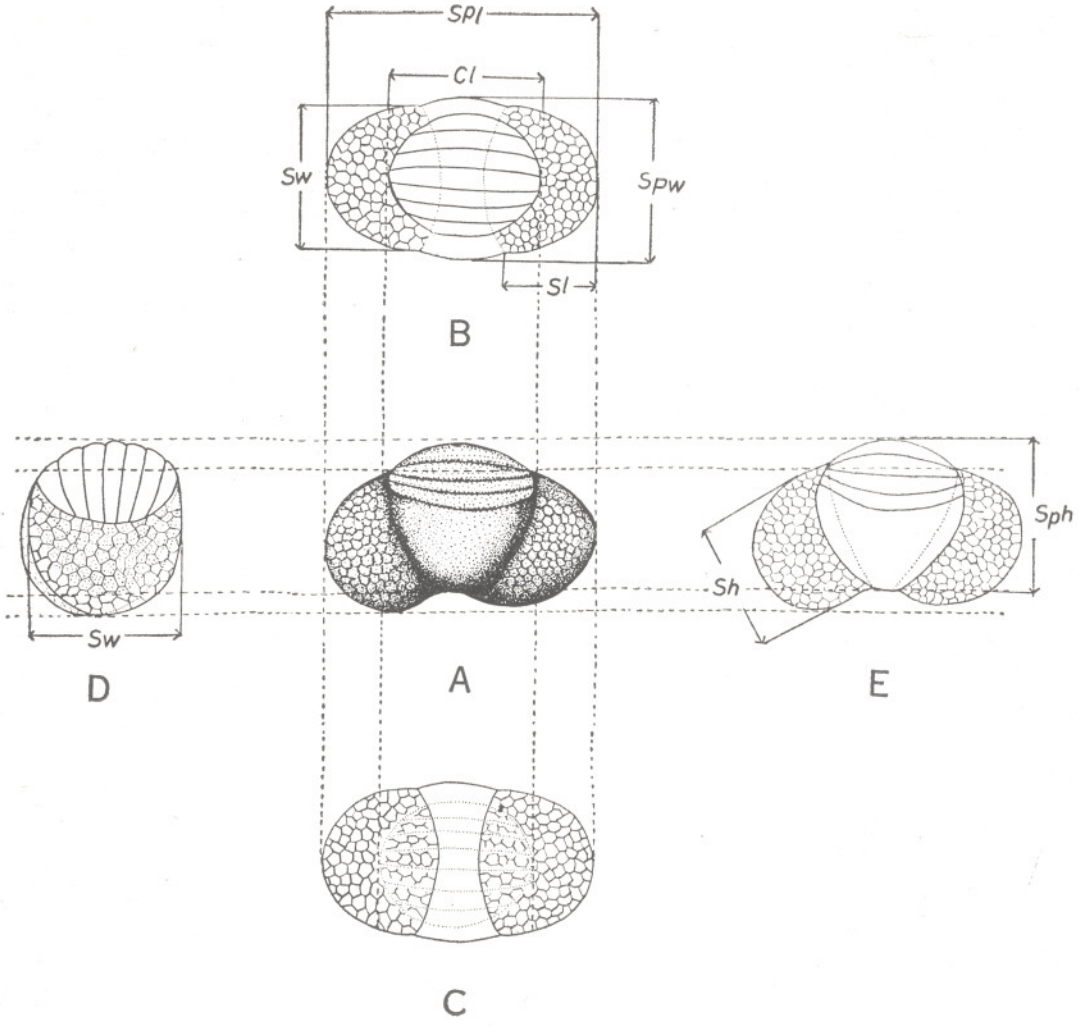
TEXT-FIG. 2 — *Arberiella vulgaris*. A, B, C and D — Dorsiventrally flattened spores. In A, B and C — the ventral side is upwards in D — the dorsal side is upwards as indicated by the smaller distance between the wings at a lower focus (dotted line). In A — the ventral wall (colpus) of the corpus is fully distended and the wings are far apart, in B and C — the wings have come closer due to inward depression of the colpus wall; E and F — Anterioposteriorly flattened spores; G — Dorsiventrally flattened spore with dorasal side up and right wing folded over the corpus and partly overlapping it; H — Spore mainly compressed in the lateral direction with one wing partially overlapping the other; I — Dorsiventrally compressed spore showing oblique striations due to torsion of the body; J — Spore compressed partially in anterioposterior and partially in lateral directions with one wing partly overlapping the other; K — Spore mainly compressed in the lateral direction with one wing almost completely covering the other; L — Dorsiventrally compressed spore with one wing folded over the corpus; M — Spore compressed mainly in the lateral direction showing folded and crumpled wings; N, O, P and Q — Spore compressed mainly in the anterioposterior direction but with varying amounts of lateral compressions. All spores × 500, Sl. No. 24.



TEXT-FIG. 3 — A — Three dimensional reconstruction of a *Striatites* spore. B — Same, dorsi-ventrally compressed with dorsal side up. C — Same as B but with ventral side up. D — Spore in A laterally compressed. E — Spore in A anterioposteriorly compressed. (*Spl* — length of spore, *Spw* — width of spore, *Sph* — height of spore, *Cl* — length of corpus, *Sl* — length of saccus, *Sw* — width of saccus, and *Sh* — height of saccus.)

views of the above four types and we regard them as compressed in intermediate planes or with their parts twisted or folded in different ways.

The margins of wings of all spores are smooth but their surface shows reticulate thickenings. The corpus of the spores shows micro-reticulations between the striations. It is not possible to say whether these ornamentations which appear micro-reticulate are thickenings of that kind or microverrucose since they sometimes seem to be microverrucose. In spores of type (3) above, the surface of the corpus which lacks striations, may even appear laevigate.

Over-maceration of the spores tended to make the striations of the corpus indistinct, and prolonged over-maceration could even wipe them out completely. In very highly macerated spores the entire cuticle of the corpus dissolves and the two sacci separate out from each other. The two free sacci of such spores are often without any mark

of the body and they appear like a reticulately sculptured rounded spore (Plate 3, Figs. 3-7; Text-fig. 1–P).

Prolonged maceration of two winged pollen grains of two extant conifer species viz., *Pinus roxburghii* and *Cedrus deodara* show that their outer exine ruptures after becoming bulged out on one side and thereafter the contents of the corpus come out wrapped in the inner exine (Plate 2, Figs. 18 and 22). The outer exine of the corpus is more resistant towards the wings but elsewhere it dissolves readily (Plate 2, Figs. 17 and 21).

Arberiella thomasii sp. nov.

Plate 1, Figs. 4 and 5

Diagnosis — Sporangium shaped masses, 0·6 to 1·95 mm long and 0·5 to 1 mm broad containing spores of *Striatites* type. Size of spores ranging from 70-176 μ in length, 50-116 μ in width and 77-86 μ in height. Number of striations 6 to 11. Size of the corpus 52-108 μ in length. Size of the wing 39-69 μ in length, 51·6-99 μ in width and 77-86 μ in height

Holotype: Slide No. D-30

Locality and Horizon: Ghusic seam, Raniganj coalfield, Raniganj Stage, India

SUMMARY AND CONCLUSIONS

Larger spores of *Striatites* type which occur in sporangium shaped clusters are referred to a *A. thomasii* sp. nov. The differences between the spores of *A. vulgaris, A. africana* and *A. thomasii* are of the same order as those between the spores of *Pinus roxburghii* and *Cedrus deodara* which were also investigated side by side.

The present study also shows that spores obtained from undehisced sporangia of *A. vulgaris* and *A. thomasii* appear to have four main types of forms due to their flattening and presenting four aspects, viz., proximal (Type 1), anterio-posterior (Type 2), distal (Type 3) and lateral (Type 4).

Mechanical and chemical action sometimes separates the wings from the body and some of our detached wings seemingly resemble previously described spores like *Sulcatisporites* (Bharadwaj, et al. 1965, Fig. 26), and *Reticulatisporites* (Bharadwaj 1962, Fig. 64). However, we are unable to confirm these observations without making a first hand comparison with the types of the above sporomorphs.

Oblique striations appearing over the corpus of some spores (Plate 2, Figs. 1-4; Text-fig. 1 — I,J,K,L; Text-fig. 2 — I) seem to be the result of a slight torsion in the corpus during flattening and *Striapollenites saccatus* Bharadwaj (1962), *Striapollenites obliqus* Bharadwaj & Salujha (1964) are presumably spores of this kind.

Some of our spores (Plate 2, Fig. 5, Text-fig. 1 — D) appear like *Distriatites* (Bharadwaj, 1962). It is possible that such spores showing criss-crossed striations are formed due to the imprint of the striations of adjacent spores during compression and fossilization. Even the wings of some of our spores show imprints of striations (Plate 2, Fig. 7, Text-fig. 1-M). In this connection, it is interesting to note that Pant and Nautiyal (1960) have also described impressions of seeds and sporangia over leaf cuticles and Pant & Gupta (1971) found imprints of the lower cuticle and stomata of a leaf over a nonstomatiferous cuticle. Some other *Distriatites* spores may represent two crossed spores compressed against each other and sticking together (see Plate 2, Fig. 6, Text-fig. 1-H). The presence of a variable number of wings in these spores may also be accounted for by this assumption.

ACKNOWLEDGEMENT

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EXPLANATION OF PLATES

PLATE 1

1. Sporangium of *Arberiella vulgaris*. Sl. No. H 1. × 75.
2. Sporangium of *Arberiella vulgaris*. Sl. No. S 2. After maceration in Shulze's fluid. × 74.
3. Spore extracted from a sporangium of *Arberiella vulgaris*. Sl. No. 13. × 500.
4. Sporangium shaped masses of spores of *Arberiella thomasii*. Sl. No. T 5. × 75.
5. Spore extracted from a sporangium shaped mass of *A. thomasii*. Sl. No. D 30. × 500.

PLATE 2

All × 500

A. vulgaris

1-4. Spores showing oblique striations. Sl. No. 20.
5. Spore showing criss-crossed striations. Sl. No. 24.
6. A *Distriatites* type of structure apparently showing 3 or 4 wings and criss-crossed striations. Sl. No. 38.
7. Spores showing imprints of striations over the wing on the lower side. Sl. No. 38.
8. Spore apparently compressed in a plane halfway between anterioposterior and lateral planes. Sl. No. 13.
9. Spore apparently compressed in a plane halfway between the anterioposterior and ventral planes. Sl. No. 13.
10. Spore apparently compressed and folded along the lateral plane. Sl. No. 13.
11. Dorsiventrally compressed spore with the dorsal side up. A small portion of the wing overlaps the corpus. Sl. No. 13.
12. Anterioposteriorly compressed spore with the wings brought closer due to slight lateral compression. Sl. No. 13.
13. Dorsiventrally compressed spore also showing slight lateral compression and folded wings.
14. Dorsiventrally compressed spore showing a collapsed wing in such a way that it lies over the striated portion. Sl. No. 13.

Pinus roxburghii

15. Mounted pollen grain. Sl. No. 10 N.
16. Dissolving corpus. Sl. No. 26.
17. Two wings separate out. Slide No. 26.
18. Corpus with inner exine and some portion of the outer exine. Sl. No. 25.

Cedrus deodara

19. Unmacerated pollen grain. Sl. No. 2.
20. Macerated pollen grain showing outer exine swollen and ruptured on one side. Sl. No. 6.
21. Outer exine of the pollen grain. Sl. No. 9.
22. Corpus with inner exine. Sl. No. 6.

PLATE 3

All × 500

1-2. Macerated spores of *Arberiella thomasii* showing initial stages in the dissolution of the corpus. Sl. No. 8 and 10 respectively.
3. A wing showing an artifact resembling a trilete mark. Sl. No. 3.
4. Separated saccus after dissolution of corpus. Sl. No. 3.
5. A mechanically separated wing looking like a spore. Sl. No. 20.
6. A wing looking like a spore. Sl. No. 4.
7. A wing appearing as reticulately sculptured rounded spore. Sl. No. 4.

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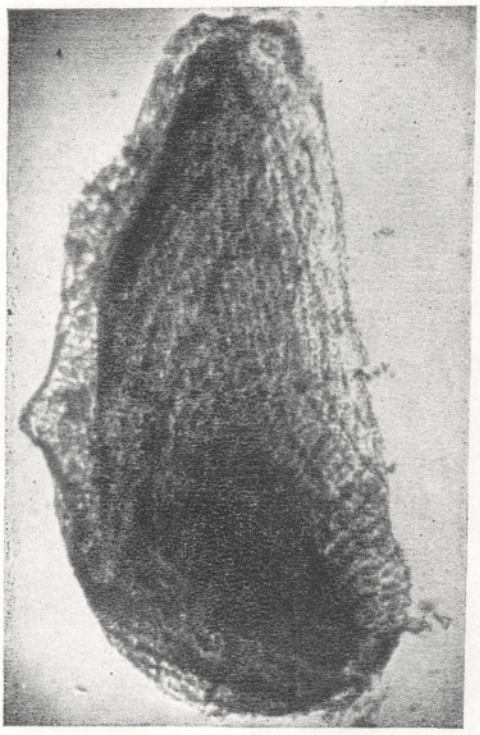

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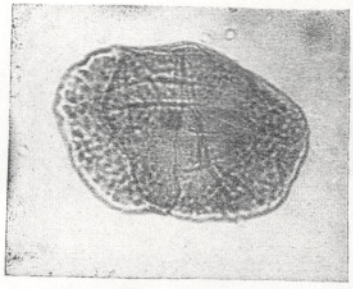

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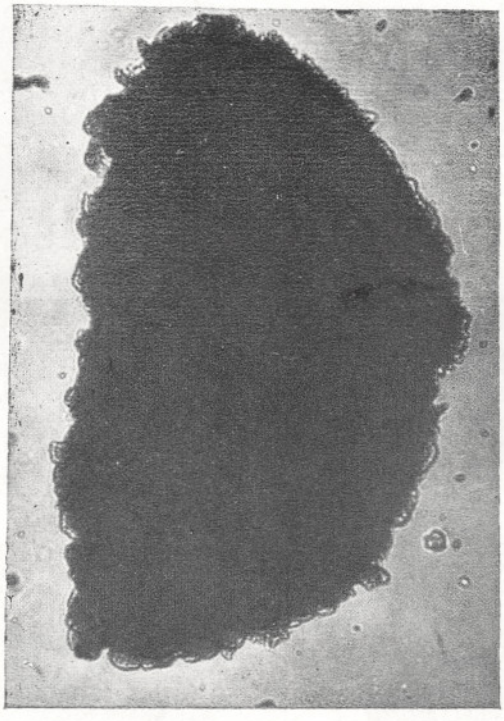

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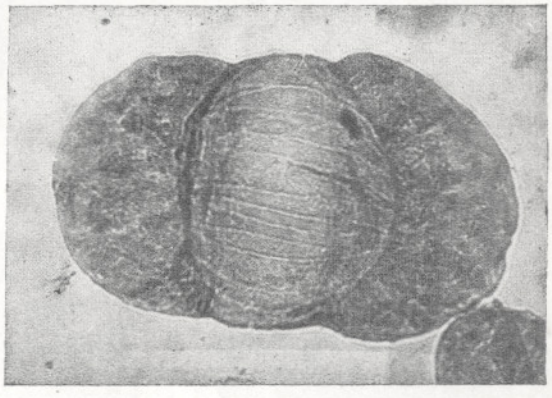

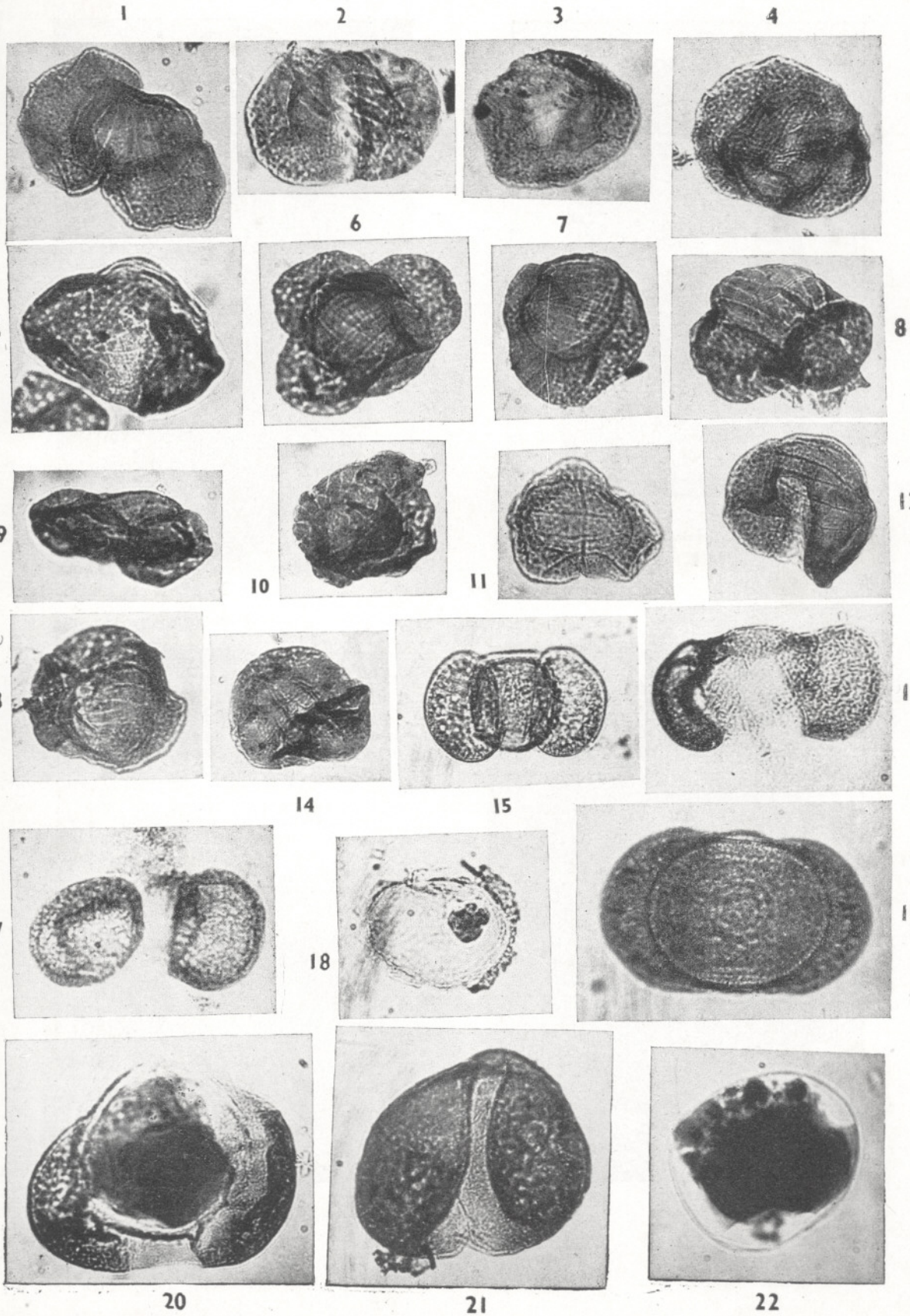
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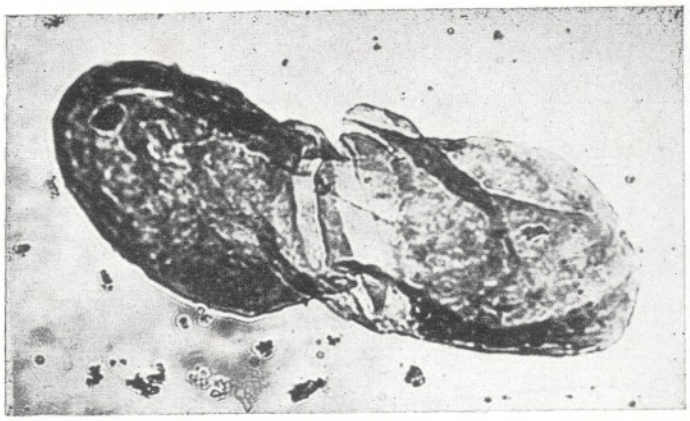

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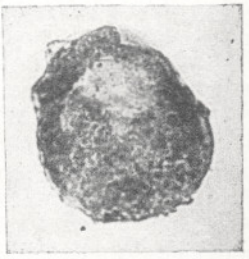

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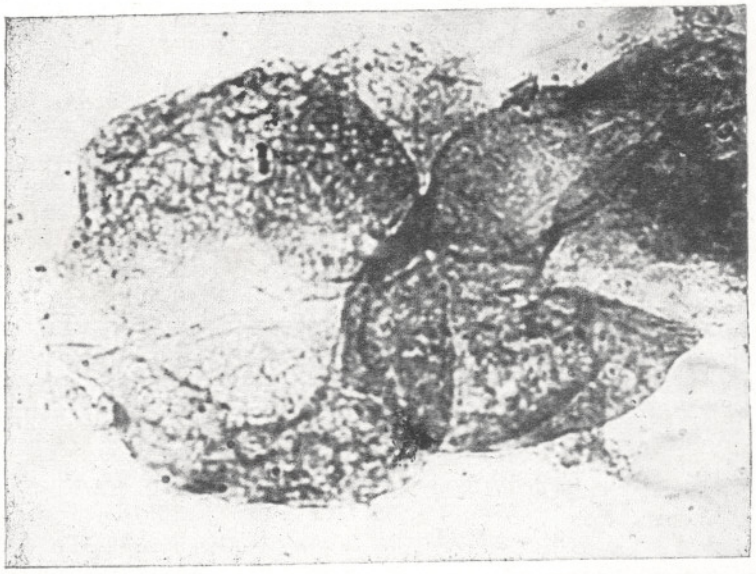

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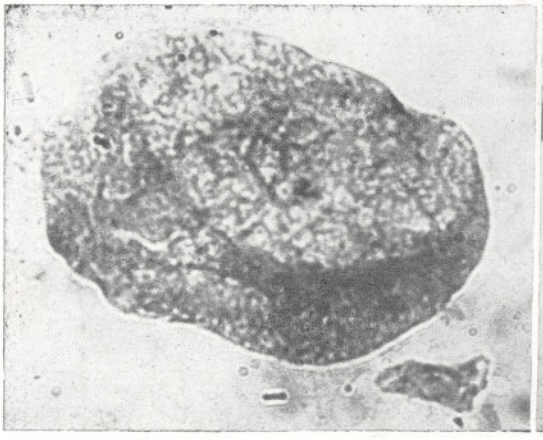

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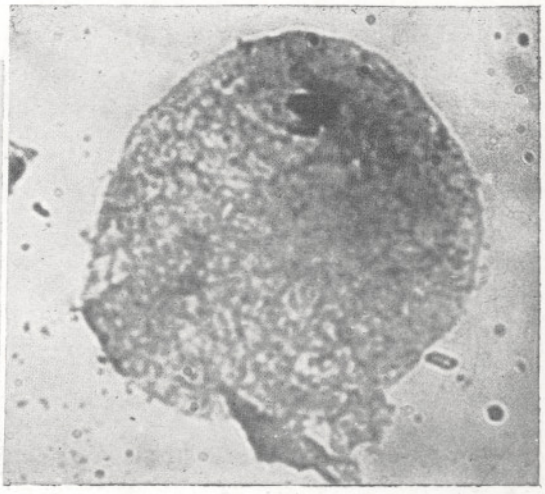

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