

STUDIES IN THE GLOSSOPTERIS FLORA OF INDIA —
15. REVISION OF THE EPIDERMAL STRUCTURE OF
NOEGGERATHIOPSIS FEISTMANTEL

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ABSTRACT

The epidermal structure of *Noeggerathiopsis indica* sp. nov. *N. gondwanensis* sp. nov. and *N. zeilleri* sp. nov. is described. The material was collected from the Ganjra Nalla beds of South Rewa basin and from the Karharbari beds of the Giridih Coalfield. Cuticles hitherto described under *N. hislopi* have been revised and reallocated in the light of the present findings with some observation on the genus.

INTRODUCTION

OF the few species of *Noeggerathiopsis* known from the Gondwanaland, *N. hislopi* (Bunb.) Feistmantel (1879) includes the largest number of leaves. This is apparently because Feistmantel made this species rather comprehensive to cover a wide range of variations in the shape and size of the leaves, their apex and venation characters. The notion that the external characters of these leaves are not reliable enough, has also led to the conglomeration of varied leaves under *N. hislopi*.

The cuticular evidence of the so-called *N. hislopi*, is however revealing. Three cuticles have so far been assigned to this species viz. by Zeiller (1896), Seward & Sahni (1920) and Höeg & Bose (1960). Surprisingly enough, all the three cuticles are distinct from each other and one did not know till now which was the valid cuticle of *N. hislopi*. Recently Saksena (1963) also described the cuticle of *N. hislopi* which is identical with that of Seward & Sahni. He has however omitted to compare and comment on the other previous records. At any rate, the above records made it increasingly clear that *N. hislopi* was not a homogeneous species and required reinvestigation.

In our opinion none of these cuticle-bearing leaves can be rightfully assigned to *N. hislopi* since we have no knowledge about the epidermal structure of the type specimen (*Noeggerathia hislopi* Bunb.) on which *Noeggerathiopsis hislopi* was based. Until such knowledge is available, *N. hislopi*

would be best retained as a species for impressions alone.

The present investigations were undertaken to study the epidermal characters of *Noeggerathiopsis* leaves collected from the Ganjra Nalla beds of the South Rewa Gondwana basin and from the Karharbari beds of the Giridih Coalfield. Fortunately enough, the material revealed the presence of all the three types of cuticles described previously under *N. hislopi*. A close examination of the external characters also showed that three distinguishable leaves were present in the collection. This new evidence has now been utilized in revising and reallocating the previous cuticles of the so-called *N. hislopi* under three new species.

MATERIAL AND METHOD

The specimens have been collected from two localities as follows:

1. From a bed of carbonaceous shale exposed in the Ganjra Nalla near its junction with the Johilla River, about 1½ miles S.W. of Birsinghpur railway station (23° 22': 81° 4'), Madhya Pradesh. The strata exposed here consist of finegrained micaceous carbonaceous shales intercalated with sandstones of variable thickness. These Lower Gondwana deposits are just below the coal seam of the Johilla Coalfield which is believed to be of Barakar age (HUGHES, 1884; FEISTMANTEL, 1882; FOX, 1931). Saksena (1952, p. 10) has, however, opined that the Ganjra Nalla beds may be either Karharbari or Barakar in age. He further points out that these beds were previously included erroneously under the name Pali beds by Virkki and Mehta. Species described from this spot are *N. indica* sp. nov. Feist. and *N. gondwanensis* sp. nov.

2. From the Central Pit, Giridih Coalfield, Karharbari Stage, Lower Gondwana. Species described from this place is *N. zeilleri* sp. nov.

Nature of Rock — Carbonaceous shale.

A thin film of a solution of Cellulose acetate in Acetone (Duco-cement is another alternative) was spread on suitable portions of the compression. The film, when completely dry, was pulled carefully together with the carbonised crust. It was then oxidised in the usual way in Nitric acid and cleared in dilute alkali. The cuticles were stained with safranin and mounted in Glycerine jelly. The slides are preserved in the Museum of the Birbal Sahni Institute of Palaeobotany.

DESCRIPTION

Genus — *Noeggerathiopsis* Feistmantel 1879

1. *Noeggerathiopsis indica* sp. nov.

Pl. 1, Figs. 1-7; Pl. 2, Figs. 8-11; Text-fig. 1

N. hislopi; Seward & Sahni 1920; Pl. 1, Figs. 1-5.

N. hislopi; Saksena, 1963; Pl. 2, Figs. 15-20; Text-figs. 2-4.

Diagnosis — Leaves simple, linear-spatulate, apex broadly rounded, tapering gradually to a \pm blunt base, margin entire; veins distinct, arising from base, straight, \pm divergent, dichotomising, about 13-20 veins per cm. in the widest region.

Cuticle amphistomatic; (?) lower cuticle with alternating stomatiferous and non-stomatiferous bands; cells of non-stomatiferous band nearly twice to several times longer than broad, $36-170 \mu \times 11-32 \mu$ in size, arranged longitudinally, \pm straight-walled, polygonal and bearing a prominent \pm conical papilla; cells of stomatiferous band relatively more cutinized, isodiametric to elongated, $18-90 \mu \times 10-28 \mu$ in size, straight-walled, without any definite arrangement, and bearing a papilla; stomata closely placed, longitudinally orientated but not in definite rows, surface of the pit rectangular to polygonal, surrounded by 4-8, heavily cutinized, subsidiary cells, often forming a ring, a rudimentary papilla occasionally present, one or two of the subsidiary cells may be polar in position, polar cell or cells often less thickened; guard cells very thin, \pm sunken, with a median slit-like aperture, size of stomata $18-46 \mu \times 7-21 \mu$ (average about $35 \times 15 \mu$), density about 140-170 per sq. mm., (?) upper cuticle relatively thicker with very rare and apparently scattered stomata; cells four-sided, longer

than broad, $40-122 \mu \times 10-22 \mu$ in size, arranged in distinct linear rows, straight-walled, surface wall thinner along the margin, smooth and unspecialised; stomata longitudinally orientated and similar in construction to those of the (?) lower cuticle.

Holotype — 5214, Pl. 1, Fig. 1A, Ganjra Nalla beds, South Rewa Gondwana basin, India. Lower Gondwana. Preserved at the Birbal Sahni Institute of Palaeobotany, Lucknow.

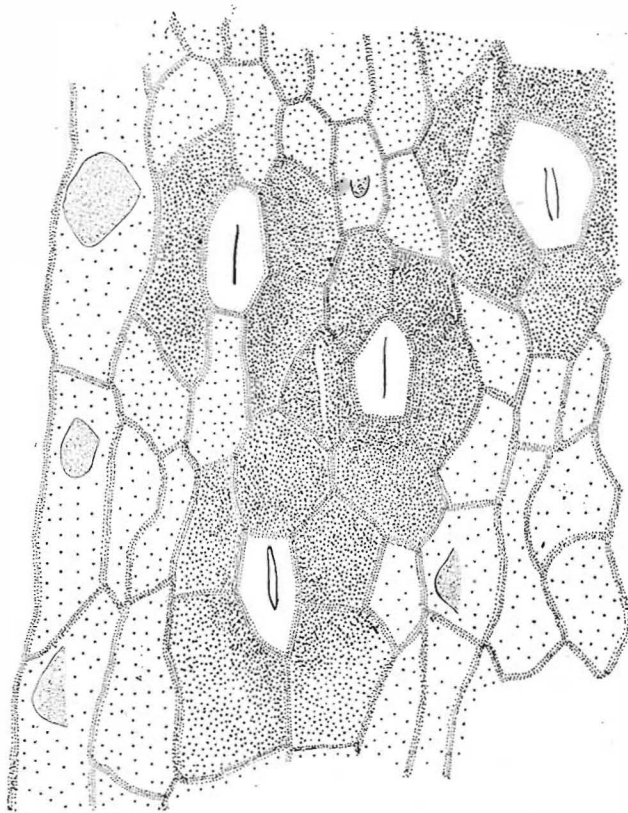
Description — The holotype (Pl. 1, Fig. 1A) is an almost complete leaf measuring 15 cm. in length and 2.8 cm. at the broadest part. The apex is broadly rounded and the two sides gradually taper to a bluntly broken base which is about 4 mm. wide. Two incomplete leaves lying close by on the same block, however, clearly show that the distal end of the frond was obtusely round (Pl. 1, Figs. 1B, 1C). Also, in both cases the leaves show to a greater or less extent some curvature at their base, one margin being more curved than the other. The veins are distinct and average about 16 per cm. in the widest part. The specimen in Pl. 1, Fig. 2 is somewhat incomplete at its base but it was apparently a shorter leaf as compared to its breadth (2.3 cm.). The veins are also closer, about 20 per cm. in the widest region. It seems that in this species the veins are slightly divergent and are usually less than 20 per cm. in the broadest part. Some specimens show what appear like fine striations in between the veins.

All the leaves figured here yielded identical cuticles. The cuticle is usually well-preserved and the two surfaces are easily distinguishable from each other. The gross differences are that on one surface (?) lower the epidermal cells are papillate and the stomata are abundant and in definite alternating bands, while on the other surface (?) upper the epidermal cells are non-papillate and the stomata are very rare and apparently scattered so that they are often missed from several preparations. The surface with rare stomata is also slightly thicker than the other surface.

The (?) lower surface of the cuticle (Pl. 1, Fig. 3) shows distinct alternation of stomatiferous and non-stomatiferous bands, the former may be from 234 to 585 μ wide, the latter is nearly so or may be broader. The cells of the non-stomatiferous band (Pl. 1, Fig. 4) are 4-6 sided (cell wall about 2 μ thick), usually about twice to several times

longer than broad, more or less arranged in rows, and vary in shape from rectangular to trapezoid or rhomboidal. They bear a prominent and relatively more cutinized papilla which is not as a rule in the centre of the cell. The papillae are more or less conical and measure about 10-15 μ at their base and 8-15 μ in height. The epidermal cells of the stomatiferous band are 4-6 sided (cell wall $\pm 2 \mu$ thick), and vary in shape from nearly isodiametric to linear elongated (PL. 1, FIGS. 5, 6; TEXT-FIG. 1). They show a much greater degree of cutinization than the cells of the non-stomatiferous band. The cells bear a papilla which is relatively smaller and less prominent than those of the non-stomatiferous band. Stomata are fairly close and longitudinally orientated in the band but are not arranged in definite linear rows (PL. 1, FIG. 5). About 2-10 stomata may, however, be seen across a band. One

of the widest stomatiferous bands is shown in PL. 1, FIG. 5 where the stomatal density is about 170 per sq. mm. The guard cells are extremely thin and show little or no cutinization with the result that the entire surface of the pit appears almost transparent (PL. 1, FIG. 6). This pit-surface is usually polygonal, or occasionally rectangular in shape. It usually shows a narrow slit-like aperture of the guard cells. The slit may or may not extend up to the full length of the pit surface. The subsidiary cells are 4-8 in number but 5 or 6 are more common (PL. 2, FIGS. 8-10). They are easily distinguishable by their heavy cutinization and their frequent tendency to form a ring around the stoma. The two poles are not, as a rule, occupied by two polar cells; there may be a single polar cell also (TEXT-FIG. 1). In several cases the polar cell or cells appear to be less cutinized than other subsidiary cells.



TEXT-FIG. 1 — *Noeggerathiopsis indica* sp. nov. A portion of the stomatiferous band showing epidermal cells and stomata. It is evident that the polar subsidiary cells do not, as a rule, occupy both the poles. Preparation from the holotype. $\times 500$.

The subsidiary cells may bear what appear like rudimentary papillae. In rare instances, adjacent stomata may share common subsidiary cells.

The (?) upper surface of the cuticle (PL. 2, FIG. 11) is slightly thicker than the (?) lower cuticle and is characterised by linear elongated, 4-sided cells (walls $\pm 2 \mu$ thick), arranged in definite rows. They are usually rectangular or trapezoid to occasionally rhomboidal. A narrow marginal zone of their surface walls is apparently less cutinized and, therefore, appears as a more or less uniformly wide, thin border surrounding a thicker central area (PL. 1, FIG. 7). The cells are otherwise unspecialised and bear no papillae. The stomata are very scarce and evidently missing from many preparations. In some bits of the cuticle, however, one or two stomata were observed (PL. 2, FIG. 11). They are longitudinally orientated and exhibit the same structure as those of the (?) lower cuticle, but have not been observed in a distinct band.

Comparison — Epidermal structures similar to *N. indica* were originally described by Seward & Sahni (1920, p. 5; PL. 1, FIGS. 1-5) and recently by Saksena (1963) under *N. hislopi*. As *N. hislopi* is henceforth retained only for impressions, these cuticle-bearing leaves are assigned to a new species, *N. indica*. The specimen of Saksena comes from the same place as ours and there is also a greater degree of correspondence between the external and epidermal characters of the two. It may, however, be pointed out that, unlike the previous authors mentioned above, we have observed 4-8 subsidiary cells in the stomata, although 7 or 8 are, indeed, very rare. We have also noted that the poles are not invariably occupied by two polar cells, but that there may be a single polar cell as well. Another feature, not hitherto mentioned, is that the polar cell or cells are often very poorly cutinized in comparison to the other subsidiary cells. Seward & Sahni noted the absence of cuticular appendages in the cells of the stomatiferous band. Their photograph (l.c. PL. 1, FIG. 2) however reveals on a few cells what appear like the remains of papillae. That the stomatiferous bands had papillate cells is now demonstrated both by our specimens as well as that of Saksena. These papillae may, however, appear less prominent than those of the non-stomatiferous band because of their relatively

smaller size and the chance of their being masked by the heavily cutinized epidermal and subsidiary cells. Besides, overmaceration may often obscure or obliterate these structures.

The (?) upper cuticle was not described by Seward & Sahni which information is provided by Saksena and now more fully by us. On this side of the cuticle Saksena (l.c. PL. 2, FIG. 18) found a stoma-like pore. That the (?) upper surface of the cuticle possesses definite, although rare, stomata has now been confirmed by us. Another interesting feature of the (?) upper cuticle is that a narrow marginal zone of the surface wall of the cells is comparatively less cutinized than the central rectangular area. The specimen figured by Saksena (l.c. PL. 2, FIG. 17) also bears this out.

The cuticle of leaves referred to *N. hislopi* earlier by Zeiller (1896) and recently by Höeg & Bose (1960) are not only distinct from each other but also differ substantially from the cuticle of *N. indica*.

The specimens of Zeiller (l.c.) are too incomplete for determining their external features. The cuticle, although insufficiently known is quite distinct owing to the complete absence of papillae. These specimens have now been removed from *N. hislopi* and placed under a new species, viz. *N. zeilleri* found in the Karharbari beds of the Giridih coalfield. The specimens of Höeg & Bose have now been replaced under another new species, viz. *N. gondwanensis* occurring in the Ganjra Nalla beds.

2. *Noeggeralthiopsis gondwanensis* sp. nov.

PL. 2, Figs. 12-16; Text-figs. 2, 3

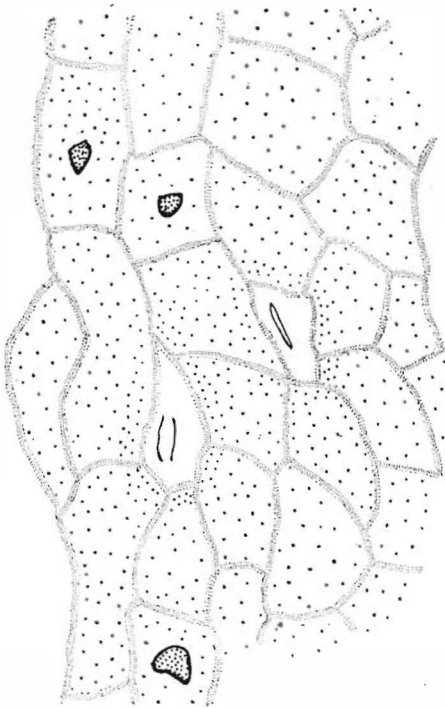
1960, *N. hislopi* (Bunb.) Feistm.—Höeg & Bose, Pl. 8, Figs. 1, 3; Pl. 9, Fig. 6 (?); Pl. 16, Fig. 6.

Diagnosis — Leaves simple, linear, \pm lanceolate, apex bluntly pointed, gradually tapering to a narrow base; veins fine, \pm indistinct, numerous, fairly close, about 22-24 veins per cm. in the broadest part, dichotomy frequent.

Cuticle hypostomatic, stomatiferous surface (?) lower) with alternating stomatiferous and non-stomatiferous bands; cells of non-stomatiferous band (PL. 2, FIG. 14) several times longer than broad, 108-216 $\mu \times$ 18-28 μ in size, \pm straight-walled, 4-5 sided, rectangular, trapezoid or rhomboidal, ar-

ranged in longitudinal rows; cells of the stomatiferous band nearly isodiametric to slightly elongated, $28-90 \mu \times 14-28 \mu$ in size, straight-walled, 4-6 sided, polygonal, not arranged in definite rows, stomata sparse longitudinally orientated but not in seriation, guard cells very thin, sunken and with a slit-like aperture, surface of the pit \pm rectangular to somewhat polygonal, nearly transparent, subsidiary cells 4-6 (rarely 7), moderately cutinized, especially on their inner side, polar cells may or may not be present, size range of stomata $18-36 \mu \times 11-18 \mu$, papillae \pm conical, occurring over cells of the stomatiferous and non-stomatiferous bands, indistinct to prominent, \pm rudimentary on subsidiary cells.

Non-stomatiferous cuticle (? upper) nearly as thick as the stomatiferous cuticle (? lower), cells several times longer than broad, $90-266 \mu \times 14-36 \mu$ in size, arranged in rows, 4-5 sided, rectangular, trapezoid or rhomboidal in shape, cell-walls (specially end-walls) nearly straight or tending to be



TEXT-FIG. 2 — *Noeggerathiopsis gondwanensis* sp. nov. A portion of the stomatiferous band showing two stomata sharing subsidiary cells. Preparation from the holotype $\times 500$.

flexuous, angles not sharp, appearance of walls rough, surface wall flat, non-papillate and unspecialized.

Holotype — No. 5219, Pl. 2, Fig. 12; B.S.I.P. Coll.

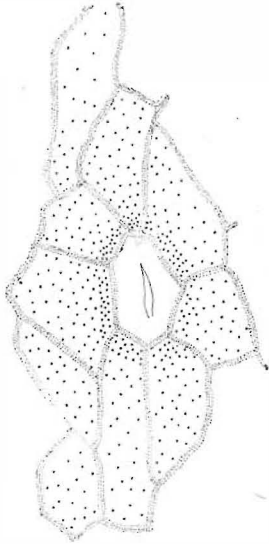
Isotype — No. 5222, Pl. 2, Fig. 13. B.S.I.P. Coll.

Description — The holotype specimen (PL. 2, FIG. 12) has an acute apex but is incomplete at its base. It measures 10.5 cm. in length and 2.5 cm. at its broadest part. The isotype (PL. 2, FIG. 13) shows the basal part of another leaf and measures 7×1.6 cm. The cuticles of both these specimens are identical. When the two specimens are adjusted one below the other it becomes obvious that the original length of the holotype specimen was presumably as much as nearly 19 cm. The veins are close, there being about 22-24 veins per cm. in the broadest part of the leaf. They are fine and usually somewhat indistinct. It appears that in this species the veins are nearly vertical and are usually not less than 20 per cm. in the broadest part.

Nearly all the leaves yielded cuticles. The cuticle is distinguished into a nonstomatiferous, non-papillate (?) upper surface and a stomatiferous and papillate (?) lower surface.

The (?) lower cuticle (PL. 2, FIG. 14) shows regular alternation of stomatiferous and non-stomatiferous bands, the former are about $104-169 \mu$ wide while the latter about $182-390 \mu$. Stomata are longitudinally orientated but do not show any serial arrangement. They are placed fairly apart and may be from 1-4 across a band. The guard-cells are very thin and may be only slightly cutinized in the close vicinity of the median slit-like aperture. The subsidiary cells are also rather weakly cutinized, their inner walls being comparatively thicker (PL. 2, FIG. 15; TEXT-FIGS. 2, 3). There are usually 4-6 subsidiary cells but rarely 7 may also be present (TEXT-FIG. 3). Polar subsidiary cells do not necessarily occupy both the poles. On the whole, the stomatal apparatus shows only slightly greater cutinization than other ordinary epidermal cells. The papillae are small and usually not well-defined. Occasionally they appear somewhat conical in shape. They occur on most of the cells of the (?) lower cuticle. The cell wall is nearly 1.5μ thick.

The (?) upper cuticle (PL. 2, FIG. 16) is nearly as thick as or only slightly thicker than the (?) lower cuticle. Stomata have



TEXT-FIG. 3 — *Noeggerathiopsis gondwanensis* sp. nov. A stoma with 7 subsidiary cells. Preparation from the holotype $\times 500$.

portant characters, for instance, the regular alternation of stomatiferous and non-stomatiferous bands, the poor cutinization of the under surface, the sparser distribution of the stomata, their structure and arrangement, the number and structure of the subsidiary cells and the presence of papillae on the under surface. Thus, there is ample evidence both morphological as well as cuticular, to transfer the Belgian Congo specimens under *N. gondwanensis* sp. nov. The diagnosis for this species therefore incorporates the minor variations exhibited by the cuticle of the Belgian Congo specimens.

N. gondwanensis sp. nov. is easily distinguished from *N. indica* by the fact that its (1) upper cuticle has almost straight to flexuous cell walls (2) the cells of the under-surface and the subsidiary cells show little or no cutinization and (3) the stomata are much sparser in the band. The external characters of the two species are also fairly distinct. They are as follows:

N. indica SP. NOV.

1. Linear spatulate.
2. Apex broadly rounded.
3. Veins distinct, \pm coarse, sparse, about 13-20 veins per cm. (often about 15-16 and usually less than 20 per cm.) in the broadest part.

N. gondwanensis SP. NOV.

1. Linear, \pm lanceolate.
2. Apex bluntly pointed.
3. Veins \pm indistinct, fine, close, about 22-25 per cm. (usually more than 20 per cm.) in the broadest part.

not been observed on any preparations. The cells are several times longer than broad, non-papillate and arranged in rows. Their walls, especially the end-walls, often tend to be somewhat flexuous and the angles are usually not sharp. The cell-wall is about 1.5μ thick and rough in appearance.

Comparison — The complete leaf described by Höeg & Bose (1960, PL. 8, FIG. 1) from the Belgian Congo under *N. hislopi* is indistinguishable from the present specimens in regard to the external form, the shape of the apex and the finer venation and its density. The epidermal structure of one of the Congo specimens is also fundamentally similar, although it shows more prominent papillae and the upper cuticle is only slightly thinner than the lower. These minor variations are in our opinion insignificant in view of the close agreement in other more im-

3. *Noeggerathiopsis zeilleri* sp. nov.

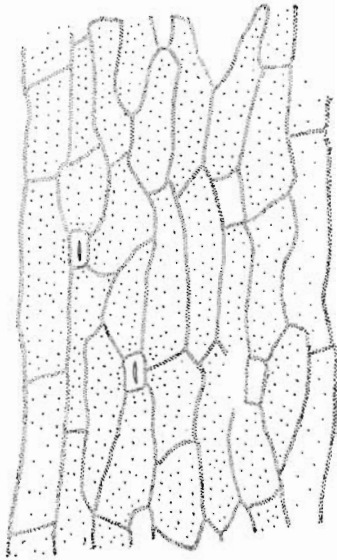
Pl. 3, Figs. 16-21; Text-figs. 4-7

1896, *N. hislopi* — Zeiller, Figs. 15, 16.

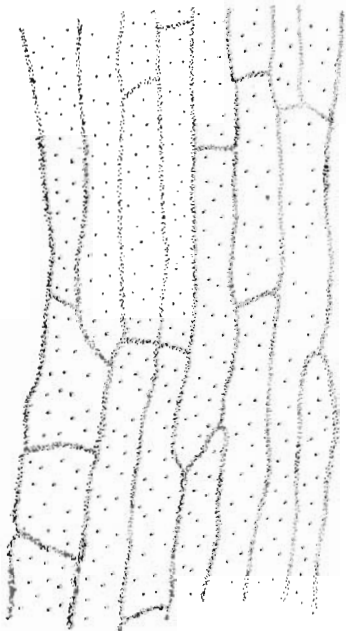
Diagnosis — Leaf lanceolate, apex bluntly pointed, margin entire, gradually tapering towards base, veins clear, arising straight from base, divergent, dichotomizing frequently, about 13-14 veins per cm. in the broadest part.

Stomata occur only on one surface. On the stomatiferous surface (Pl. 3, FIG. 21) stomata arranged in alternate bands; cells of stomatiferous band polygonal and arranged in longitudinal rows, stomata sparsely set, longitudinally orientated and irregularly distributed (TEXT-FIG. 6), stomatal apparatus (Pl. 3, FIG. 22; TEXT-FIG. 7) haplocheilic and monocyclic, slightly sunken; guard cells

nearly transparent, covering an area about 24μ long and 12μ wide with a longitudinal slit-like opening ($\pm 16 \mu$ long); each stoma



TEXT-FIG. 6 — *Noeggerathiopsis zeilleri* sp. nov. A portion of the stomatiferous band on the stomatiferous (Lower) surface showing epidermal cells and few stomata. Preparation from the holotype. $\times 250$.



TEXT-FIG. 5 — *Noeggerathiopsis zeilleri* sp. nov. Epidermal cells of the non-stomatiferous band on the stomatiferous (Lower) surface. Preparation from the holotype. $\times 250$.

encircled by 5-6 subsidiary cells measuring $60-90 \mu \times 18-25 \mu$, subsidiary cells rectangular, polygonal or trapezoid, non-papillate and like the ordinary cells of stomatiferous band; occasionally two stomata have common subsidiary cells. Non-stomatiferous band wider than stomatiferous band; cells (PL. 3, FIG. 21; TEXT-FIG. 5) commonly much elongated, rectangular or trapezoid, measuring $120-170 \mu \times 16-30 \mu$, placed in linear rows, non-papillate and thinner than the cells of stomatiferous band.

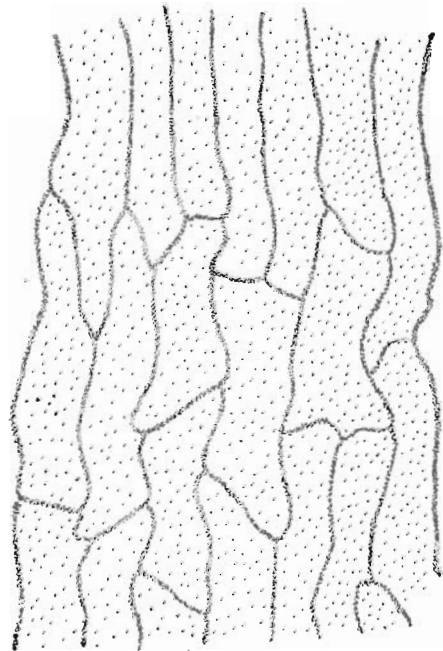
Non-stomatiferous surface (PL. 3, FIG. 20; TEXT-FIG. 4) thicker than stomatiferous surface; cells comparatively larger, rectangular, trapezoid, measuring $170-108 \mu \times 34-50 \mu$, placed in linear rows; cell-walls straight to somewhat flexuous with rough or toothed outlines, cells devoid of papillae or hairs.

Holotype — No. 31363/424 (PL. 3, FIG. 17).

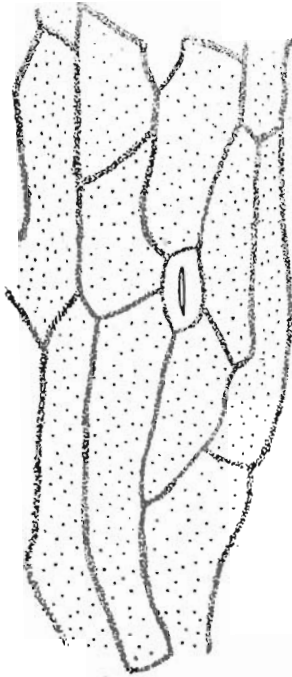
Isotypes — No. 31367/424 (PL. 3, FIG. 18); No. 31350/424 (PL. 3, FIG. 19).

Locality — Central pit, Karharbari stage, Giridih Coalfield.

Description — The leaves are lanceolate in shape with tapering base and bluntly pointed apex. Most specimens are incomplete but taper towards the apex in a manner which suggests that the apex was bluntly



TEXT-FIG. 4 — *Noeggerathiopsis zeilleri* sp. nov. Epidermal cells of the non-stomatiferous (Upper) surface. Preparation from the holotype. $\times 250$.



TEXT-FIG. 7 — *Noeggerathiopsis zeilleri* sp. nov. A stoma with 5 subsidiary cells. Preparation from the holotype. $\times 500$.

pointed. The small fragment in Pl. 3, Fig. 19 shows the nature of the apex. The size of the specimens varies from 8-14 cm. \times 1.8-3 cm. The leaves are widest near the middle portion. Veins are divergent (PL. 3, FIG. 18) and about 13-14 per cm. in the widest region. The holotype (PL. 3, FIG. 17) is nearly complete but for a small portion at the apex and base. It measures 8 \times 1.9 cm. and shows about 13-14 veins per cm. in the broadest region. All the leaves of this species possess a carbonized crust which yielded small fragments of cuticles on maceration.

A feature of some interest is the rough or somewhat toothed appearance of the cell outlines on the non-stomatiferous surface (PL. 3, FIG. 20). It may be noted that this feature is not observed in the cells of the stomatiferous surface.

Comparison — *N. zeilleri* externally resembles *N. indica* but in the former the veins are more divergent and the apex is bluntly pointed. In the shape of apex *N. zeilleri* approaches *N. gondwanensis* but the veins in the latter species are much crowded, \pm indistinct and nearly vertical. The cuticle of

N. zeilleri is quite distinct from the rest species in being non-papillate. The cuticle described by Zeiller (1896) under *N. hislopi* is closely similar to that of the Karharbari specimens and is, therefore, transferred under *N. zeilleri*.

CONCLUDING REMARKS

Noeggerathiopsis is an important constituent of the Glossopteris flora of India and is widely known from Australia (ETHERIDGE, 1918, FEISTMANTEL, 1890, WALKOM, 1921), Belgian Congo (HÖEG & BOSE, 1960, SEWARD, 1931), South America (DOLIANITI, 1948, ARCHANGELSKI, 1958) and from the Kuznezsk basin (ZALESSKY, 1937; NEUBERG, 1948). Stratigraphically, it is more common in the lower part of the Indian Lower Gondwana (Upper Carb.—Lower Permian) viz. the Talchir, the Rikba and the Karharbari stages, where it is associated with abundant remains of *Gangamopteris* (FEISTMANTEL, 1879; SURANGE & LELE, 1956, 1957). It becomes increasingly rarer in the overlying Barakar and Raniganj (Up. Perm.) stages. The Triassic records of *Noeggerathiopsis* are extremely few and rather imperfect (FEISTMANTEL, 1882, LELE, 1956, 1962).

The genus *Noeggerathiopsis* is now represented by about seven species from the Gondwanaland strata, viz. (1) *N. hislopi* (Bunb.) Feistm.—here restricted for impressions only (2) *N. hislopi* var. *subrhomboidalis* Feistm.—from India only, (3) *N. stoliczkanus* (Feistm.) Arber— from India and S. Africa (4) *N. gondwanensis* sp. nov.— from India and Belgian Congo, (5) *N. spathulata* Dana— from Australia only (6) *N. zeilleri* sp. nov.— from India and South Africa and (7) *N. indica* from India. From the Kuznezsk basin Neuberg (1948) describes nine species under *Noeggerathiopsis* none of which occur in the Gondwanaland deposits. Of these records, the cuticular structure of *N. indica* sp. nov. *N. gondwanensis* sp. nov., and *N. zeilleri* sp. nov. are completely known.

Eversince the institution of *N. hislopi* by Feistmantel, a considerable amount of *Noeggerathiopsis* material has been rather indiscriminately ascribed to that species from nearly all important parts of the Gondwanaland and also from other regions. That these assignments have been made in several cases on superficial resemblances (*sensu* FEISTMANTEL) is revealed by the distinct

cuticular structure of leaves referred to *N. hislopi* by Zeiller (1896), Seward & Sahni (1920), Höeg & Bose (1960) and Saksena (1963). Of these, the cuticle described by Seward & Sahni and Saksena is reassigned to a new species, *N. indica* on the basis of additional evidence from the Ganjra Nalla specimens. The leaves described by Zeiller (1896) and Höeg & Bose (1960) have now been removed to the new species *N. zeilleri* and *N. gondwanensis* respectively. The relative differences in the epidermal structure of the three species are given in Table 1. A closer examination of the leaves makes it clear that the three species *N. indica* sp. nov., *N. gondwanensis* sp. nov. and *N. zeilleri* sp. nov. can also be distinguished on the basis of their external characters.

The present findings point out that the cuticles of *Noeggerathiopsis* species appear to show a fundamental agreement in the fact that the stomatiferous surface has a regular alternation of stomatiferous and non-stomatiferous bands, and the stomata are longitudinally orientated but do not occur in regular files. Also, the upper surface is non-papillate in all the cases so far studied. It is at the same time clear that (1) in *N. gondwanensis* and *N. zeilleri* stomata are found only on one surface, but in *N. indica* they occur on both the surfaces and (2) in *N.*

indica and *N. gondwanensis* the stomatiferous surface is papillate but in *N. zeilleri* both the surfaces are non-papillate. The present evidence is not sufficient to assess the value of these differences which, as our knowledge grows, might throw light on the generic status of *Noeggerathiopsis*.

The question of the relation between *Noeggerathiopsis* and the essentially Northern genus *Cordaites* is another interesting palaeobotanical puzzle. In regard to gross external features there is a certain resemblance between the two, but this seems to have no special significance in itself as similar gross features may be found in a number of other leaves not necessarily cordaitalean. As far as details are concerned, the leaves of *Cordaites* do not convey the same impression as those of *Noeggerathiopsis*. For instance, the commonly large size of *Cordaites* leaves, their thick and fleshy nature, the different degree of thickness in different regions of the leaf, their long and somewhat strap-like shape, their tendency of apical splitting, their spiral mode of attachment by a broad, inflated, semi-clasping base are some of the more striking features that lend the *Cordaites* foliage a distinct aspect. On the other hand, the leaves of *Noeggerathiopsis*, as far as one can judge from the compressions, appear to be more or less uniformly flat and

TABLE 1 — RELATIVE DIFFERENCES IN THE EPIDERMAL STRUCTURE OF NOEGGERATHIOPSIS SPECIES

<i>N. indica</i> SP. NOV.	<i>N. gondwanensis</i> SP. NOV.	<i>N. Zeilleri</i> SP. NOV.
1. Cuticle amphistomatic; stomata rare on one side, frequent on the other.	1. Stomata present only on one surface.	1. Stomata present only on one surface.
2. Cells of stomatiferous and non-stomatiferous bands on the stomatiferous surface are papillate.	2. Cells of stomatiferous and non-stomatiferous bands on the stomatiferous surface are papillate.	2. Cells of the stomatiferous surface are non-papillate.
3. Stomata are closely placed about 140-170 per sq. cm. 2-10 stomata across a band; size range, of stomata $18-46\mu \times 7-21\mu$.	3. Stomata sparse, 1-4 across a band; Size range of stomata $18-36 \times 11-18$.	3. Stomata sparse, 1-3 or 4 across a band, size of stomata $24 \times 12\mu$.
4. Subsidiary cells 4-8.	4. Subsidiary cells 4-6, rarely 7.	4. Subsidiary cells 5-6.
5. Cells of the stomatiferous band and specially the subsidiary cells are heavily cutinized.	5. Cells weakly cutinized, subsidiary cells, specially along their inner walls relatively thicker and distinguishable from other epidermal cells.	5. Subsidiary cells as weakly cutinized as other epidermal cells of the stomatiferous band and are hardly distinguishable from other epidermal cells.
6. Upper cuticle thicker than lower, cell walls straight, surface thinner along margins.	6. Upper cuticle nearly as thick or slightly thicker than lower, cell walls, specially end-walls \pm flexuous.	6. Upper cuticle thicker than lower, cell walls straight to \pm flexuous, toothed in appearance.

thick. The detached specimens often show a broken proximal end which appears irregularly blunt. In rare cases, for instance, the specimens from Ganjra Nalla (PL. 1, FIG. 1b, 1c) as well as the Belgian Congo specimen of Höeg & Bose (1960, PL. 8, FIG. 1) show that the proximal end was roundly obtuse. Also in all these cases the basal part is clearly curved which perhaps bears some relation to the mode of attachment. No peculiarities in the base of the leaf are, however, known nor is there any evidence of organic connection between *Noeggerathiopsis* leaves and an axis. A number of peculiar specimens are, however, on record, in which several leaves are arranged around a central point in a radial manner suggesting that the leaves were borne in a sort of a whorl or a close spiral (ETHERIDGE, 1918; SEWARD & SAHNI, 1920, PL. 1, FIG. 10; WALKOM, 1921). The preservation of these specimens raises interesting questions specially because in no case is any recognizable axis found in the same plane which contains the leaves.

Seward (1917) and subsequently Seward & Sahni (1920, pp. 5, 6) have been inclined to consider *Noeggerathiopsis* as identical with *Cordaites* on the grounds of a fundamental agreement in their epidermal structure. In the light of more recent studies on the *Cordaites* foliage (HARMS & LEISMAN, 1961) and our present knowledge about *Noeggerathiopsis*, it may be reasonably contended that the epidermal characters of the two genera are distinguishable.

1. In *Noeggerathiopsis* the stomata are never arranged in regular files or series in a stomatiferous band which is so prevailing

a character of *Cordaites* stomata. The only known exception to this is *Cordaites rotundinervis*.

2. In general a non-papillate cuticle seems to be as frequent in *Cordaites* as a papillate cuticle in *Noeggerathiopsis*. Papillate cells, if exceptionally found in *Cordaites*, are not as a rule confined to the lower surface as in *Noeggerathiopsis*.

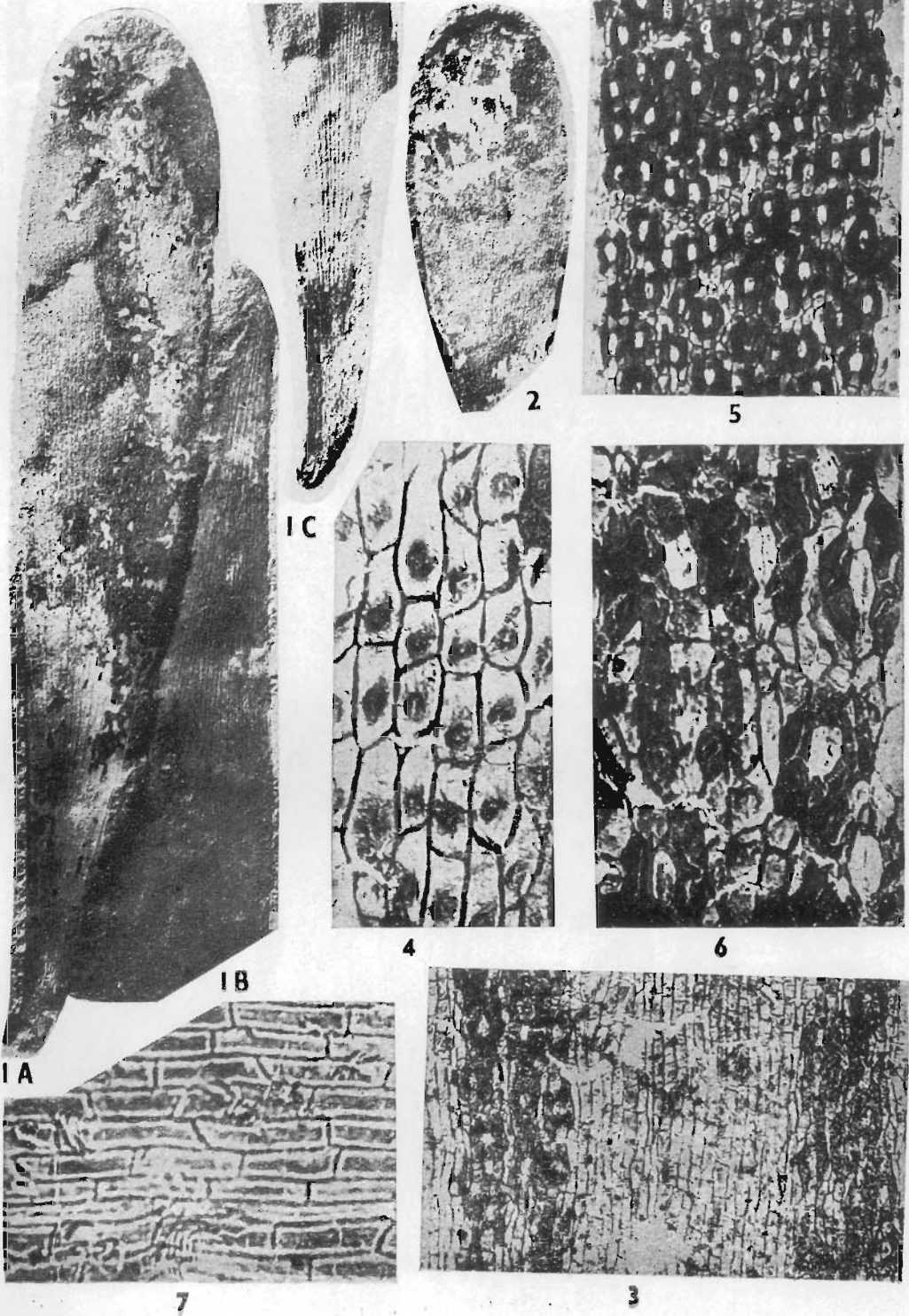
3. In *Noeggerathiopsis* the subsidiary cells are 4-8 in number, presence of polar cells at both the poles is not a rule, and the occurrence of common subsidiary cells is rare. On the contrary, in *Cordaites*, the subsidiary cells are 4-6 (more often only 4) in number, two of these are invariably polar in position and also comparatively smaller than other subsidiary cells. The polar and lateral subsidiary cells frequently share similar cells of the neighbouring stomata.

4. In *Cordaites*, the cuticular extensions from the subsidiary cells overhang the stomatal opening and form an epistomal chamber. This structure is not evident in *Noeggerathiopsis*.

From the above account, it is clear that in their morphological aspect as well as in their epidermal characters, the leaves of *Noeggerathiopsis* stand apart from those of *Cordaites*. Besides, while the anatomy of *Cordaites* leaves (irrespective of the question whether all such leaves were born on stems or branches having the anatomical characters of *Cordaites*) is fairly known (HARMS & LEISMAN, 1961) we have absolutely no knowledge about the internal structure of *Noeggerathiopsis*. This situation further necessitates the retention of *Noeggerathiopsis* as separate from *Cordaites*.

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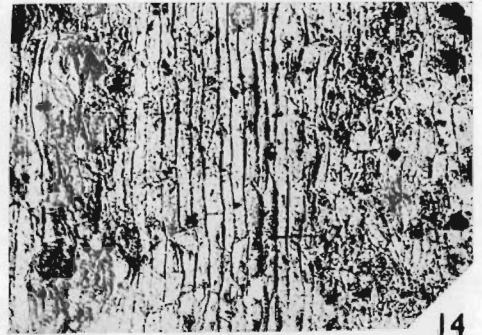
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EXPLANATION OF PLATES

PLATE 1

Noeggerathiopsis indica sp. nov.

- 1A. Holotype, No. 5214, × Nat. Size.
- 1B. Incomplete leaf; the left hand margin near base shows a little bending. No. 5214, × Nat. Size.
- 1C. Basal portion of a leaf showing a curvature at its proximal end. No. 5214, × Nat. Size.
2. A smaller frond. No. 31725/556, × Nat. Size.
3. Lower cuticle showing alternation of stomatiferous and non-stomatiferous bands. Preparation from specimen. No. 5221, × 60.
4. Cells of the non-stomatiferous band showing prominent papillae. Preparation from specimen No. 5213, × 50.
5. One of the widest stomatiferous bands showing the scattered, papillate epidermal cells and longitudinally orientated stomata. Preparation from specimen in Fig. 1A, No. 5214, × 80.
6. A portion of a stomatiferous band enlarged. Preparation from specimen in Fig. 1A. No. 5214, × 250.
7. Epidermal cells of the upper cuticle showing a uniformly wide thin marginal zone surrounding a thicker central area. Preparation from specimen No. 5218, × 250.

PLATE 2

Noeggerathiopsis indica sp. nov.

- 8, 10. Two stomata with 4 and 8 subsidiary cells respectively. The polar cells are relatively less cutinized. Preparation from specimen in Fig. 1A. No. 5214, × 500.
9. A stoma with 6 subsidiary cells. Preparation from specimen in Fig. 1A. No. 5214, × 500.

11. Epidermal cells of the upper cuticle. A stoma is seen near the right hand margin of the photo. A circular, monosaccate spore is seen near the left hand margin of the photo. Preparation from specimen No. 5221, × 120.

Noeggerathiopsis gondwanensis sp. nov.

12. Holotype, No. 5219, × Nat. Size.
13. Isotype, No. 5222, × Nat. Size.
14. Lower cuticle showing alternation of stomatiferous and non-stomatiferous bands. Preparation from specimen in Fig. 12. × 100.
15. A portion of the stomatiferous band showing distribution of epidermal cells and the sparse stomata. Nearly half of the portion on the left hand margin shows elongated cells of the non-stomatiferous band. Preparation from specimen in Fig. 12. × 250.
16. Upper cuticle showing rows of elongated cells. The walls are nearly straight to somewhat flexuous. Preparation from specimen in Fig. 12. × 100.

PLATE 3

Noeggerathiopsis zeillevi sp. nov.

17. Holotype, No. 31363/424, × Nat. size.
18. Isotype, No. 31367/424, × Nat. size.
19. Isotype, No. 31350/424, × Nat. size.
20. Upper cuticle showing the somewhat flexuous cells and their toothed walls. Preparation from specimen in Fig. 17, × 250.
21. Lower cuticle showing a stomatiferous band flanked on each side by a non-stomatiferous band. Preparation from specimen in Fig. 17, × 250.
22. A stoma with 5 subsidiary cells. One of these cells is shared by another stoma seen at the top. Preparation from specimen in Fig. 17, × 500.