FOSSIL PLANTS FROM THE K'UANGSHANCH'ANG COAL SERIES OF NORTH-EASTERN YUNNAN, CHINA

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ABSTRACT

A collection of 34 species of plants from K'uangshanch'ang of the K'uangshanch'ang Coal Series of Huiche (formerly Tungchuan) district, north-eastern Yunnan, China, has been studied. It is a flora represented by Equisetales, Sphenophyllales, Pteridospermae (or Filicales), Cordaitales, and other groups. The majority of the fossils are fronds of *Sphenopteris* and *Pecopteris* and a large number of seeds.

Nine species are identical with or closely comparable to those from the Lower Shihhotze Series of central Shansi (which, according to Professor Halle, is of early Permian age); five are identical with or closely comparable to those from the Upper Shihhotze Series of the same province; seven are related to the Late Carboniferous flora of Sumatra; and four either identical or related to the Permian flora of Korea. This shows that the plants most probably belong to the earliest Permian age.

Five species are described as new: *Pecopteris huichensis, P. Sahnii, P. yunnanensis, Tobleria minor* and *Cornucarpus huichensis.*

The last-named species has a seed in organic connection with a sphenopteroid pinnule. Both geographically and in its palaeobotanical composition the Yunnan flora serves as a link between the *Gigantopteris* flora of China and Korea on the one side and that of Sumatra on the other. It suggests that the geological age of the K'uangshanch'ang Coal Series is earliest Permian.

The specimens do not contain even a single species in common with the Indian Gondwana flora, a fact suggesting that there was no land bridge between Cathaysia and Gondwanaland in the early Permian age.

INTRODUCTION

IN 1943 I received from the Mining Department of Yunnan University and the Yunnan Geological Survey twenty small pieces of plant fossil specimens found by Dr. H. M. Meng and others from a locality (*see* MAP on p. 246) named Heyching, of K'uangshanch'ang (103°7′: 26°6′), *ca.* 58 km. N.E. of the Tungchuan district. This district has been newly renamed as the Huiche district. Originally there were about 300 pieces, but unfortunately the greater part of the collection was lost in transit.

The fossils are preserved in a very soft grey shale. The shale splits very easily into regular layers and is extremely fine-grained, bearing very good impressions of leaves, seeds, etc. Judging from the nature of the rock, there is no doubt that all the specimens come from the same bed of lake deposition.

By carefully splitting the small pieces, I found at least 34 species of plant fragments.

Attempts were made to prepare cuticles and spores from several of the specimens but without success, and indeed success was hardly to be expected in view of the almost complete removal of carbonaceous matter. For the same reason it was useless to attempt to prepare transfers.

I wish to express here my sincere thanks to the Mining Department of Yunnan University and the Yunnan Geological Survey for the supply of the specimens, and to Professor T. G. Halle of Stockholm and the late Professor B. Sahni of Lucknow for their kind suggestions.

DESCRIPTION

Equisetales

1. Annularian shoot

Pl. 1, Fig. 1

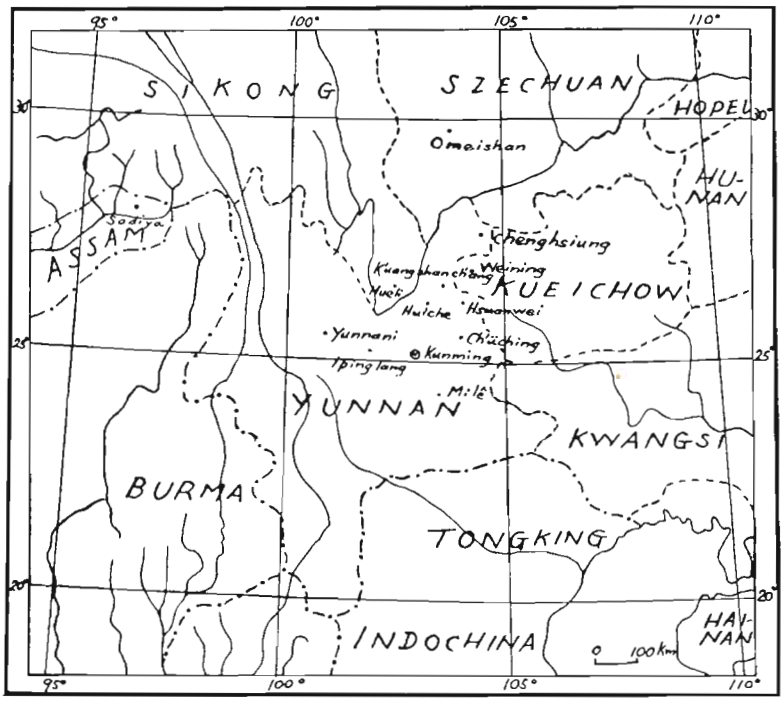
A few fragments of shoots have been found which, although too incomplete to be specifically identified, appear to belong to Equisetales and may possibly be related to *Annularia.*

The best specimen is shown in Fig. 1. It consists of a slender axis about 0·4 mm. in thickness, with a portion of a leaf-whorl attached. The latter has 6-8 segments, which are united basally and spread out obliquely like a fan. The segments are lanceolate and appear to be unequal in length, ranging from 6 to 9 mm. and *ca.* 1 mm. in their broadest part. Each segment possesses a slender (but distinct) midrib, extending to the apex.

2. Calamarian leaves or scales

Pl. 1, Fig. 2

Pl. 1, Fig. 2 shows the appearance of the specimen. The lower part, which appears



Map of Yunnan with its neighbouring countries, showing the fossil localities mentioned in this paper.

to be the node bears tapering teeth. The node is more or less smooth and shows the outlines of epidermal cells distinctly. The teeth taper to an acute apex; their positions suggest that they were originally fused laterally with their neighbours but have split into irregular groups on preservation.

The segments have a length of 1·5 cm. and are about 2 mm. broad near the base. The surface is marked by some longitudinal ridges, extending from the base to the apex.

In general this specimen is comparable to certain Calamarian leaves found in Sumatra (JONGMANS & GOTHAN, 1935, PL. 1, FIG. 4; PL. 2, FIG. 3 & PL. 3, FIG. 4) but is much larger. Our specimen compares to some extent with *Calamites semicircularis* Weiss from the Middle Upper Carboniferous of Belgium (HIRMER, 1927, p. 386, FIG. 461).

3. Leaves of *Asterophyllites*

Pl. 1, Fig. 3 at A

Some long slender leaves have been found. They are at least 4 cm. long and generally 0·2 mm. broad. Most of them possess a distinct midrib and some slender parallel striations on the surface.

It is difficult to identify these fragments of leaves in the absence of stems. Somewhat similar leaves have been described and figured from central Shansi as *Asterophyllites* by Halle (1927 a, p. 37; PL. 11, FIG. 9).

Sphenophyllales

4. *Sphenophyllum Thonii*, cf. var. *minor* Halle

Pl. 1, Figs. 4, 5

Two well-preserved isolated leaf fragments have been obtained. One of them is shown in Pl. 1, Figs. 4, 5.

The leaf is 2 cm. long and *ca.* 1 cm. broad in the widest part. The shape is obovate, tapering sharply towards the proximal end, and slightly concave in the middle but rounded at the two corners. Its margin is entire. The veins are very delicate, repeatedly dichotomous, spreading outwards from the base of the leaf. The ultimate branches reach up to the edge of the leaf. The number of veins across the apical part of the

leaf is *ca.* 30, while those which meet the lateral margin of the leaf, arising from the base to one of the distal corners are, *ca.* 17. The veins near the base of the leaf are 6-8 in number. They gradually merge into a single broad, but short, midrib (PL. 1, FIG. 5).

Leaves resembling our specimen have been described from central Shansi as *Sphenophyllum Thonii* var. *minor* by Halle (1927 a, PL. 9, FIGS. 2, 3). The leaf from Yunnan compares more closely with Halle's Fig. 3. Halle, however, is not sure about the identity of the fossil in his Fig. 3 with *S. Thonii* var. *minor*.

Our leaf is also comparable to some specimens of *S. Thonii* var. *minor* found by Kawasaki in Korea (1934, PL. 17, FIGS. 8, 9; PL. 52, FIG. 136). It seems that my specimen has a slightly denser venation.

Kawasaki found some more specimens of *Sphenophyllum* from Korea and named them as *S. Hallei* (1939, p. 12; PL. 1, FIGS. 5, 6 & TEXT-FIG. 1). These leaves show some similarities with my specimen and with those from central Shansi (HALLE, 1927 a, PL. 9, FIGS. 3, 4), but Kawasaki's Text-fig. 1 is perhaps not very accurate. In view of the variations found in the leaves of *Sphenophyllum*, it is not unlikely that the specimens of *S. Thonii* var. *minor* described by Halle and Kawasaki from central Shansi and Korea, the specimens of *S. Hallei* figured by Kawasaki from Korea, and our specimen from Yunnan all belong to one species.

In this place I may mention that two specimens from Korea, named *S. Thonii* var. *minor* Sterzel (KAWASAKI, 1939, PL. 8, FIGS. 43, 44), are quite different from my specimen. The main points of difference are that they are larger, have more truncated apices and straight margins, and that the veins do not merge into a single broad strand near the base of the leaf.

Filicales and Pteridospermae

GENUS *Sphenopteris* BRONG.

5. *Sphenopteris Norinii* Halle

Pl. 1, Figs. 6, 7

There seems to be little doubt that the specimen figured in Pl. 1, Figs. 6, 7 is identical with *Sphenopteris Norinii* already described and figured from central Shansi by Halle (1927, pp. 62, 63; PL. 12, FIG. 5). The Yunnan fossil appears to have come from nearer the leaf apex than the one shown in Halle's figure. From a rachis 1 mm. thick are seen arising pinnate segments, 1·3 cm. long, at an angle of about 50°. The pinnules seem to be oval-deltoid with ill-preserved venation so that their outline is not very clearly defined. The pinnules decrease in size progressively from the base of the pinna outwards. The basal pinnules are about 3-4 mm. long. The venation is of characteristically sphenopteroid type.

6. *Sphenopteris*, cf. *Grabaui* Halle

Pl. 1, Figs. 8, 9

The frond is of unknown habit. The pinna measures at least 3 cm. long with a prominent rachis about 1 mm. in width. The pinnules are about 7-9 mm. long, divided into 4-6 lobes on either side of the mid-vein, opposite to subopposite, arising from the rachis at an angle of 50°-60°; the midrib is well defined, persisting almost to the tip of the pinnule. The secondary veins were not well preserved; they are forked at least once as they enter the lobes.

This specimen is closely comparable with *Sphenopteris Grabaui* Halle from central Shansi (HALLE, 1927 a, PL. 13, FIG. 8) both in the size and the shape of the leaflets.

7. *Sphenopteris* sp. *A*.

Pl. 1, Fig. 10

The frond is of unknown habit, bi-pinnate or more highly divided. The rachis of the pinna is not so thick as in *S.* cf. *Grabaui*. The pinnules are attached alternately to the rachis at an acute angle. They are narrowly ovate, divided into 5-6 lobes on either side of the midrib. The midrib is delicate, giving off repeatedly forked branches into each lobe.

Our fossil compares to some extent with *Oligocarpia* (*Sphenopteris*) *Gothanii* Halle (1927 a, PL. 14, FIGS. 7, 9), but in the latter the pinnules are much shorter, with the lobes shorter, and sharply defined.

8. *Sphenopteris* sp. *B*.

Pl. 2, Figs. 13-16

Figs. 13-16 show three specimens which belong probably to the same species. They are being provisionally put together because of a close similarity in the size and shape of their pinnules. The specimen in Figs. 15 and 16 shows a number of circular black spots irregularly placed on the pinnules on both sides of the rachis. Each spot is about

0·8 mm. in diameter and seems to be very slightly depressed below the surface, the depression being filled with a much-cracked carbonized crust. This appearance strongly suggests that they may be sori, but all attempts to prepare spores from them have failed. It is a pity that the preservation is not better, and does not enable us to decide whether the spots are sori or not.

The pinnules here are short (*ca.* 4-5 mm. in length) with 3-4 lobes on each side of the midrib. The venation is indistinct but truly sphenopteroid.

This form appears to be different from the species described so far from China, Korea and Sumatra. But because of the fragmentary nature of our specimens no new specific name is being given.

9. *Sphenopteris*, cf. *Gothanii* Halle

Pl. 2, Figs. 17, 18

This is not a well-preserved fragment. From the rachis a number of deeply lobed leaflets are seen to arise alternately. The venation is sphenopteroid, the midrib being fairly thick.

Our specimen seems nearly identical with a leaf of *Oligocarpia* (*Sphenopteris*) *Gothanii* (Halle, 1927 a, Pl. 14, Fig. 5) from central Shansi. It appears, like Halle's specimen, to be the terminal part of a frond.

Genus *Pecopteris* Brong.

10. *Pecopteris*, cf. *taiyuanensis* Halle

Pl. 1, Figs. 11, 12

Fig. 11 shows a small fragment of a pinna with three pinnules; a portion of the counterpart is shown enlarged in Fig. 12.

The pinnules appear nearly touching, arising at an angle of about 50° from the rachis, and are broadly oblong, 8 mm. long and 3·5 mm. broad. The proximal edge of the lamina is slightly decurrent at the base; and the apex is rounded. The midrib is distinct but slender, slightly arching at the base and merges into the secondaries at some distance below the apex. The secondary veins are dense, bifurcating only once, and very close to the midrib.

This small fragment seems identical with the specimens described as *P. taiyuanensis* from central Shansi by Halle (1927 a, pp. 84-86; Pl. 21, Figs. 1-4), but owing to the fragmentary nature of our specimen it is not possible to be certain of the identity.

It may be mentioned that the specimens found in Sumatra and described by Jongmans and Gothan as *P.*, cf. *Cistii* Bgt. (1935, pp. 115, 116, Pl. 36, Figs. 4, 5; Pl. 37, Fig. 3), closely resemble both my specimen and *P. taiyuanensis*. It is possible that all the three may be a single species.

11. *Pecopteris Wongii* Halle

Pl. 2, Figs. 19, 20

The specimen shown in Figs. 19, 20 is identical with *Pecopteris Wongii* described by Halle (1927 a, pp. 87-92; Pl. 22, Fig. 5) from central Shansi.

The fragment of the penultimate pinna shown in Fig. 19 is about 5 cm. long and about 3 cm. broad. The ultimate pinnae are 1·7 cm. long and 4 mm. broad. The pinnules are very small, ovate to roundly oblong, about 2 mm. long and 1·8 mm. broad and united for a short distance at their bases. The pinnules become confluent at the distal end of the pinnae where they appear only as slight lobes. The venation is indistinct, but some pinnules show an arched midrib, with a few secondary veins. The rachis of the ultimate pinnae shows, arranged along its whole length, 8-10 minute but very definite pit-like scars. Four or five of them are placed usually alternately on either side of the rachis but one quite frequently sees two or three of these scars occurring on the rachis itself (Pl. 2, Fig. 20). They probably represent scars of hair bases.

12. *Pecopteris huichensis* sp. nov.

Pl. 2, Figs. 21-24; Pl. 3, Figs. 26-29, 30 at A, 31, 32, 36

The fronds shown here are the most common of all the species in the collection. There are both fertile and sterile pinnae amongst them: for the present all are being referred to the one species, which is regarded as new, because, though the specimens are fragmentary, they do not afford a close comparison with any known species of *Pecopteris*.

In spite of the number of specimens in hand the general form and degree of dissection of the frond is still unknown, but from the specimen shown in Pl. 3, Fig. 27 (which is fertile) it is clear that the fertile frond was at least twice pinnate. Unfortunately this is the only specimen in which the actual tip of a pinna is preserved, hence a comparison with the sterile frond

must be confined to the more proximal parts of the pinna and here there is, on the whole, a fairly close resemblance between the two. The arrangement of the pinnules and the characters of the venation are identical though the fertile pinnules do not show us the veins so clearly as the sterile, and are as a rule somewhat narrower distally, with a slight tendency to become falcate. One pinna, though predominantly sterile, bears some fertile pinnules (PL. 3, FIG. 32). This specimen is important as it links up all the specimens under the one species.

Maceration of fertile specimens has not brought forth any spores.

Diagnosis: *Pinnae oblong, over* 5 *cm. long and up to* 1·5 *cm. broad. Pinna rachis in the basal part* 1 *mm. or more thick, with irregular longitudinal wrinkles, traversed by a well-marked, strongly zigzag, main vein from the angles of which the pinnules come off alternately at about* 60°-70°. *Pinnules oblong,* ca. 5 *mm. long and* 2 *mm. broad, with a broadly rounded apex. Towards the distal part the pinnule sometimes slightly tapering, especially in the fertile frond; in sterile pinnules the venation prominent, the veins being coarse. Midrib persisting almost to the tip and giving off half a dozen widely forked secondaries on either side at an angle of about* 45°. *Forking starting almost at once when the veins leave the midrib. Veins usually arched, and as a rule once, rarely twice, furcate.*

The fertile pinnule (FIGS. 29-31) bears 12-14 elliptical sori, each of 4-6 sporangia, on either side of the midrib, the centre of each sorus being marked by a small black depression in which a portion of the carbonized crust generally persists. As far as can be made out, the sporangia are separate and distinct from each other, appearing like so many little humps round the central depression. But as the preservation is not very good, it is possible that they may be fused together at the base, in which case the sorus would have to be regarded as a synangium and the designation *Asterotheca* would be justified. At present, however, as the photograph shows (PL. 3, FIG. 31), there is no evidence of any such fusion.

There is a general resemblance in the shape and size of the pinnules with those of *Pecopteris hirta* (HALLE, 1927a, PL. 24, FIGS. 1, 2), but the venation of the Shansi fossil is not so open and coarse as in our specimens. The veins of *P. hirta* are slender and more numerous, there being at least 8 pairs in a pinnule, and they fork only some distance away from the midrib. In our specimens the lamina is devoid of hairs which is a characteristic feature of *P. hirta.*

Another superficial comparison is possible with *P.* (*Asterotheca*) *Norinii* of Halle (1927a, PL. 17, FIG. 9) so far as the size and shape of the sterile pinnules is concerned. But the venation of *P. Norinii* is more close and the veins are repeatedly furcate.

The above are the only Chinese species comparable with the present specimens. There is also one European species, *Pecopteris* (*Asterotheca*) *Daubreei,* from the Permian of France (ZEILLER, 1906, PL. 9, FIGS. 1, 2), whose sterile fronds come quite close to the Huiche form. The venation in the French species is, however, more close; the veins are more delicate and at least twice furcate.

13. *Pecopteris* sp. *A.*

Pl. 4, Figs. 37-43

The frond shown here is only an impression of a fertile pinna which may be regarded as a new species because it does not afford a close comparison with any known species of *Pecopteris.* The specimen is fragmentary and no sterile pinna has been obtained. It is better not to describe it as a new species until more specimens are available.

The pinna is oblong, about 5·5 cm. long and about 1·2 cm. broad. Pinna rachis is about 1 mm. thick with irregular longitudinal wrinkles. It is traversed by a well-marked, strongly zigzag, main vein from the angles of which the pinnules come off alternately at an angle of about 60°. The pinnules are oblong, *ca.* 4·5 mm. long and 2 mm. broad, with a rounded apex; towards the distal part of the pinna the pinnules are slightly falcate. The lateral veins are inconspicuous.

The pinnule bears on either side of the midrib a row of about twelve sori, the sori in the two rows being subopposite and placed distinctly nearer the midrib than to the margin of the pinnule. The central point of each sorus is a depression in which the carbonized crust is still preserved; the sporangia are only seen in the form of impressions on the rock, but these are clear enough to show the cell outlines (PL. 4, FIGS. 41-43).

In each sorus there are 4-6 elliptical sporangia (FIGS. 40, 41). Those along the

midrib of the pinnules look roundish and smaller than those towards the outer margin (FIGS. 39, 39a). Without further material it is difficult to decide whether the sporangia were actually unequal in size, as they appear to be. If this was the case, this would be a very good distinctive character, unique, so far as we know, for the fertile fronds of the *Pecopteris* type, and possibly deserving of generic rank. On the other hand, this appearance may only be due to the inner sporangia (possibly placed on the sloping sides of the midrib) being seen almost in end view, while the outer ones, placed more horizontally, were viewed from the side.

It is very difficult to judge from the present specimen whether the sporangia are slightly united at the base or definitely free from each other. Some reticulations seen on the walls of the sporangia under high magnifications most probably represent the cell outlines (FIGS. 41-43). Macerations yielded no spores or cuticles of the sporangia.

There is some resemblance in the shape and size of the pinna and the pinnules of this specimen with *Pecopteris huichensis* (PL. 2, FIGS. 21-24), but the position and structure of the reproductive organs of the two forms are quite different: (i) the sori of the present specimen are situated distinctly nearer to the midrib, and (ii) the sporangia are definitely elliptical. Such characters mark out the present specimen as a distinct species.

14. *Pecopteris arcuata* Halle

Pl. 3, Figs. 30 at B, 35

This is a small fragment, which is identical with the specimens of *Pecopteris arcuata* from central Shansi, described by Halle (1927 a, pp. 80, 81; PL. 19, FIGS. 1, 2, 11, 12).

The pinna measures about 13 mm. broad. The pinnules have a decurrent base and arise at an angle of about 60°-80° with the rachis. Their shape is oblong, about 75 mm. long and 3 mm. in width, with a broadly rounded apex. The midrib is rather faint, arching, dissolving near the apex; and the secondary veins are furcate, arising at an angle of about 30° with the midrib, strongly arching. General surface of the lamina is finely striated.

Halle says that this species is very variable. It is with his typical form, figured in Pl. 19, Figs. 1, 2, 7, 11, 12, that my specimen shows the closest resemblance.

15. *Pecopteris Sahnii* sp. nov.

Pl. 3, Figs. 30 at C & D, 33

The two fragments of sterile pinnae shown in Fig. 30 at C and D on the whole agree closely with *Pecopteris cyathea* (Schlotheim) as figured by Kidston from the Upper Carboniferous of Britain (1924, pp. 488-491, PL. 67, FIGS. 3, 3a); but at the same time they present some well-defined features which make it difficult to identify them either with that species or with any other *Pecopteris* known to me. Although the material is scanty, it is well preserved. I, therefore, propose to refer the fragments to a new species and name it after the late Professor B. Sahni of Lucknow University, Founder-Director of the Birbal Sahni Institute of Palaeobotany, Lucknow.

Diagnosis: *Pinnae linear, over* 3·5 *cm. long and about* 13 *mm. broad, with a fairly broad rachis, about* 1 *mm. thick, smooth, but with faint markings of scales. Pinnules subopposite, contiguous, rather stiff, arising at an angle of about* 60°-90° *with the rachis, oblong-linear, with a broadly rounded apex. Midrib distinct and straight, either extending up to the apex or forking just short of it. Secondary veins about* 13-15 *on either side of the midrib, arising at an angle of about* 40°, *sometimes slightly arched in the apical and the basal region of the pinnules. Veins as a rule rather stiff, straight, subopposite and generally simple except the basal vein on the lower side of each pinnule, which arises from the pinna rachis and is usually bifurcated with the lower arm of the fork arched forwards. Basal vein on the upper side of the pinnule also slightly arched forward but always simple.*

The main distinctive features of the species lie (i) in the rather rigid habit of the contiguously placed oblong pinnules, (ii) in the usually rigidly straight and parallel secondary veins, all of which except the basal one are simple, (iii) in the fact that the basal veins arch forward, and (iv) in the fact that the basal vein on the lower side of the pinnule originates directly from the rachis and is usually bifurcated (PL. 3, FIG. 33). The upper surface of the lamina, when examined under a strong lens, shows minute, close set ellipsoid tubercles indicating the arched outer walls of the epidermal cells and perhaps suggesting a somewhat xerophytic habit which is in consonance with the stiff nature of the pinnules. There

is no sign of hairs on the upper surface which is the only side exposed to view in the fragments.

In the form and arrangement of the pinnules the present specimens have some resemblance to *P. hemitelioides* Brong. but the lateral veins of the latter species are stated to be invariably simple (KIDSTON, 1924, p. 522) and the rachis bears numerous small scales (KIDSTON, 1924, p. 520). Specimens of the same species have also been described as *P.* (*Asterotheca*) *hemitelioides* Brong. from central Shansi by Halle (1927, PL. 25, FIGS. 11-14). The leaflets in Halle's specimens are not touching and the veins are all simple, including the basal veins of the pinnules.

Our proposed new species differs from *P. arborescens* Goeppert in the much greater length of the pinnules and in the characteristically forked basal vein which originates directly from the rachis.

From *P. cyathea* (Schl.) it is distinct in the more oblique position of the lateral veins which, moreover, are nearly all simple, and in the character of the basal vein just mentioned.

Some specimens have been recorded from Yunnan by Halle (1927, PL. 1, FIG. 7) and from Malaya by Edwards (1926, p. 178; FIG. 1). Both authors have compared them to *P. cyathea*. Owing to their very bad preservation it is very difficult to judge whether they are really identical with my specimens, but this seems unlikely because their habit is not so rigid.

Professor Halle (1936, p. 24) has recorded a *Pecopteris* specially comparable to the type "*cyathea-arborescens-hemitelioides*" from east of Chuchiehtse, in the district of Ch'üching (*see* MAP). This is interesting, as the locality from which the present specimens were collected is about 100 km. from Ch'üching.

16. *Pecopteris yunnanensis* sp. nov.

Pl. 4, Figs. 46, 47

This is only a fragment of a pinna, but it is well preserved and luckily both fertile and sterile pinnules are present. It offers no comparison with the recorded species of *Pecopteris*. It is mainly in the venation that it differs from the forms known to me.

Diagnosis: *Pinna about 12 mm. broad with a somewhat broad rachis. Pinnules oblong, slightly separate sometimes contiguous, arising at an angle of about 60°, 6 mm. long and 2·5 mm. broad, with a broadly rounded apex. Midrib of pinnule decurrent on the pinna rachis, not prominent, but about half as thick as the rachis, having an undulated appearance owing to the strongly arched course of two strong decurrent secondary veins. Secondary veins, 8 or 9 in number, arising from either side, at a small angle (not more than 30°) from the midrib but soon arching away from it, and at once forking twice, nearly at the same level, to form a well-defined fascicle of 4 veinlets which meet the pinnule margin at about 75°-80°.*

The fertile pinnules are not well preserved and very few well-formed sori are visible, but on one or two pinnules there are clear indications that 8 or 9 sori were present on either side of the midrib. In other cases only groups of individual sporangia can be made out.

The arching course of the veins in their proximal part, combined with the lateral margins of the midrib, impart a curiously undulated appearance on which the specific name has been based. A somewhat similar effect is seen also in the pinna rachis but it is less pronounced because of the comparatively less sinuous course of the veins in the rachis.

The pinnules of this specimen have a general appearance like those of *Pecopteris polymorpha* Brongniart (1828, pp. 331, 332; PL. 113, FIGS. 1-4a), which has been found in Korea (KAWASAKI, 1934, pp. 110-113; PL. 25, FIGS. 40-43; PL. 31, FIGS. 65, 66) and Sumatra (JONGMANS & GOTHAN, 1935, p. 111, PL. 33, FIG. 3; PL. 34, FIG. 1); but the midrib in the latter is quite distinct while in my specimens it is not much in evidence at first sight, as it bears delicate zigzag lines and is lost among the secondaries. Zeiller (1890, p. 60; PL. 8, FIGS. 8, 8a) also states that in *P. polymorpha* the midrib of the pinnules is not decurrent.

17. *Pecopteris* sp. *B.* (cf. *P. cyathea*)

Pl. 3, Fig. 34

This is a rather poorly preserved specimen, in which the venation is not clear. The pinna is linear, about 4 cm. long and about 1·3 cm. broad, with a fairly broad rachis, about 1 mm. thick, smooth but with faint markings of scales. The pinnules are subopposite, contiguous at base, arising at an angle of about 60°-90° with the rachis,

oblong-linear, about 6 mm. in length with a rounded apex.

The midrib is quite distinct, straight, nearly extended into the apex. The secondary veins are very faint, but in some portions they are distinctly arched and bifurcate once or more.

At a glance this fossil looks rather similar to *Pecopteris Sahnii* (PL. 3, FIG. 30 at C & D), but the present specimen is not rigid in general appearance; the pinnules have a rather tapering rounded apex and have arched and bifurcated lateral veins.

It might be compared with *P. cyathea* (Schlotheim) as figured by Kidston (1924, pp. 488-491, PL. 69, FIGS. 3, 3a) from the Upper Carboniferous of Britain. But the venation of the present specimen is too faint for specific identification.

Sze (1934, p. 598; PL. 2, FIG. 2) has described some specimens as *P. arborescens* Goeppert from Suiyuan, north China, which look rather similar to mine except that all the secondary veins of the Suiyuan specimens are not divided. Some authors have, however, united *P. arborescens* with *P. cyathea*. But according to Kidston (1924, p. 491) these two species are distinct. They can be easily distinguished by the greater length of the pinnules of *P. cyathea* in proportion to the width than is the case in *P. arborescens*, by their gradually concentrating into a blunt point and also by a mixture of simple and bifurcated veinlets which has not been observed to occur in the pinnules of *Asterotheca arborescens*.

18. *Pecopteris* sp. *C*.

Pl. 4, Figs. 44, 45

This is a detached fragmentary pinna, 1·8 cm. broad with a rather broad rachis, nearly 2 mm. near the lower end of the specimen. The pinnules are oblong (8×3 mm.), arising at an angle of about 65°-75° and touching; their apex is round. The midrib looks rather distinct, distantly punctate in the basal half, and slender. The secondary veins are about 9-10 on either side of the midrib, arising at an angle of about 60°, arching, bifurcating near the midrib. Occasionally the distal arm of a fork, rarely both arms, divide once more just beyond the first dichotomy.

This solitary and rather poorly preserved specimen does not seem to offer close comparison with any known form; it may possibly represent a new species but with the unsatisfactory material in hand it would be wrong to give it a name.

Cordaitales

19. *Cordaites* sp.

Pl. 2, Fig. 25; Pl. 5, Fig. 67 at A

This collection includes several fragmentary specimens of a rather peculiar type of flat, ribbon-like leaves, two of which are shown in Figs. 25, 67 at A. The lamina is marked with a series of strongly developed and very closely placed veins, almost like ribs, as many as 50-70 in a width of 1 cm. The markedly zigzag course of the ribs in some places is due to an accident of preservation. There is no evidence of bifurcation or anastomoses.

The length and width of the leaves are unknown. The broadest part preserved in these specimens is about 17·5 mm. but the actual breadth may be slightly wider. The bigger specimen shown in Pl. 2, Fig. 25 has a length more than 8 cm. The leaf base is broad and slightly auriculate, with a concave margin where it partly enveloped the stem. In the auricles the lamina is distinctly thinner and membranous, while the veins here are also much finer and more closely set, converging slightly towards the margin of attachment to the stem.

Some parts of the specimens are preserved in carbonized state but no cuticle could be obtained by maceration.

A comparison of the general appearance can be made with the specimens described by Jongmans and Gothan (1935, pp. 157, 158, PL. 57, FIGS. 1-3) from Sumatra as *Poacordaites* sp. The venation of *Poacordaites*, both in the number and character of the ribs, appears very similar with that in the present leaves.

According to Seward (1917, p. 227) "the name *Poacordaites* is employed for narrower linear leaves with an obtuse apex", but it is safer not to use this subgeneric name for the present specimens until more complete material is obtained.

Semina Gymnospermarum

20. *Tobleria minor* sp. nov.

Pl. 5, Figs. 48, 49

Diagnosis: *Seeds platyspermic, provided with two tapering horns at their anterior end;*

shape subtriangular ovate, somewhat scale-like with a broad round base; size extremely small, about 1 *mm. long (including the horns) and about* 0·9 *mm. at the greatest width near the base; central sinus widely open (marking an angle of* 45°) *and deep (about* 0·5 *mm. in depth). Main body divided into two equal lobes, marked by a middle furrow running in continuation of the sinus. Nucules two, demarcated by a thin round line. Surface of the seed on the nucular part quite smooth, while the rest marked by longitudinal striations (including the horns), showing platyspermic nature.*

These specimens resemble *Tobleria bicuspis* Jongmans and Gothan from Sumatra (1925, Pl. 2, Figs. 8a-c, 9; Pl. 37, Figs. 4-6) in all respects, except in the size which is about 6 times less than that in the Sumatran species. The present specimen is, therefore, being made into a new species, *T. minor*.

The genus *Tobleria* differs from *Cornucarpus* in having double nucules (Jongmans & Gothan, 1925, pp. 294, 295). So far this is the first discovery of the genus from China.

21. *Cornucarpus huichensis* sp. nov.

Pl. 5, Figs. 50, 51, ? 52, 53

There are two seeds: one is found in connection with a sphenopteroid pinnule and the other is detached.

Diagnosis: *Seed platyspermic (?) companulate, about* 3·5 *mm. long and* 1·9 *mm. broad, with the broadest part near the middle. Apex broad, truncated and slightly concave, with the corners slightly projecting forward from the angles of the wing. Body slightly asymmetrical, the left side being slightly swollen in the middle portion and lower than the right. Basal end tapering attached by means of a rudimentary pedicel to the dorsal surface of the base of a sphenopteroid pinnule. Surface of the seed rather finely striated in the longitudinal direction. Nucule lenticular, about* 2·5 *mm. long and* 0·7 *mm. broad, located at the basal and medial portion of the seed. Wing(?) divided into three layers. The outer thin marginal layer, about* 0·1-0·2 *mm., covers the whole surface of the seed, the middle and the inner layers separated by a thin curved line. A small cavity situated at the middle of the apex visible through the wing.*

The above diagnosis refers to the smaller seed, shown in Figs. 50, 51 in which the letters *o*, *m*, *i* and *c* indicate the outer, middle and inner layers of the wing (?) and the cavity at the middle of the apex. I am inclined to think that the pedicel of the seed is attached to the lower (dorsal) surface of the leaf, because the veins are prominent.

The detached seed shown in Pl. 5, Figs. 52, 53 may belong to another species. It is comparatively broader than the attached one, about 4 mm. long and 4 mm. broad, with a truncate apex.

The attached pinnule is in general more or less ovate-lanceolate, slightly lobed, about 3·7×6·5 mm. Lobes appear subopposite, bluntly rounded. Midrib distinct; secondary veins of the same thickness as the midrib, arising alternately at an angle of about 30° and branching laterally three or four times; the ultimate branches dissolving out near the margin of the pinnule.

Seeds of this type are interesting. Unfortunately the attached frond is not complete, so I am not able to identify the pinnule specifically. Halle (1927a, pp. 199-205; 1929) has described several bicornute seeds from central Shansi under the name *Cornucarpus* and found some of these seeds attached to fern-like fronds. Adopting his generic diagnosis (Halle, 1927a, p. 201) for the Huiche specimens, which are no doubt a new type of *Cornucarpus*, I propose to name them *Cornucarpus huichensis* sp. nov.

Among the described seed-bearing species of *Sphenopteris*, *S. tenuis* Schenk (Halle, 1929, pp. 2-5; Pl. 1, Figs. 1-5) has something in common with my specimens: (i) the position of seeds on the dorsal surface of the base of pinnules, (ii) the principal venation of the frond, and (iii) the shape of the seeds.

The specimens named as *C. megalatus* from Korea by Kawasaki (1931, Figs. 271, 272) are somewhat similar, but much larger than ours, and *C. megalatus* has a more deeply concave apex. The points of resemblance are that the wing in that species is also marked by fine striations and has a very thin marginal layer, as shown in Kawasaki's Fig. 272. But a close comparison is not possible without further knowledge of the Korean species.

22. *Cornucarpus* sp. *A*.

Pl. 5, Figs. 60, 61

This seed appears platyspermic (?). It is ovate-oblong, 3-3·5 mm. long and 1·4-1·8 mm. broad, and very finely striated on its

surface by extremely minute irregular oblique lines. Its apex is truncate and concave, with the corners slightly projecting. The wing is not well developed, about 0·2 mm. wide, along the two sides of the seed. The nucule is rather indistinct. (N.B. The rather broad border round the seed, marked in Fig. 60 at *x*, is *not* the wing of the seed, but due to a colouration of the rock round it.)

By removing the crust in the basal part of the seed, some inner tissues have been exposed, which show the narrow basal part of the nucule (FIGS. 60, 61) slightly bent to one side. The outline of the rest of the nucule, faintly visible in Fig. 60, is shown with dotted line in Fig. 61. Thus the nucule is found to be somewhat companulate in outline and about 1 mm. across the middle.

This seed bears no comparison with any of the reported forms. Probably it is a new species of *Cornucarpus*. Owing to the imperfection of the material, I prefer not to name it for the present.

23. *Cornucarpus* sp. *B*.

Pl. 5, Figs. 62, 63

This seed appears platyspermic (?). It is ovate, about 3 mm. long including the horns, and 2 mm. across the greatest breadth slightly above the middle. Its apex is wide, truncated, about 1·2 mm. broad and slightly concave with two short stout horns projecting from the corners. Its base is tapering and rounded, and with the two sides unsymmetrical because of the imperfect preservation of the " wing " (or ? sarcotesta). The nucule looks lenticular, marked by a curved line on the right side and slightly more than 1 mm. broad. The wings have not been well developed.

Although this specimen is probably similar to *Cornucarpus* sp. *A*, yet, due to the badly preserved state of both fossils, no comparison is possible.

24. *Samaropsis* sp.

Pl. 5, Figs. 67 at B, 54, 55

This seed is probably platyspermic, obovate-lanceolate, about 4·8 mm. long and 2·5 mm. broad, and composed of an ovate central nucule encircled by a broad rim. The nucule, represented by a thick cast, measures 3 mm. in length and 1·9 mm. in breadth. The marginal rim is entire, with a deep apical sinus, the two sides of which make an angle of about 30° (this does not come out distinctly in the photograph) (FIG. 55). The thickness of the rim is about 0·8 mm. near the base and apex, but measures about 0·5 mm. in the middle portion of the two sides. The surface of the whole seed seems quite smooth.

It is not clear whether the marginal rim represents a real wing or merely the flattened sarcotesta. It is also not certain whether the apical sinus is structural. It may be due to the tearing of the sarcotesta. In the absence of definite horns I prefer to name the seed, provisionally, *Samaropsis* sp.

The seed resembles slightly that of *Pteridozamites* (*Sphenopteris*) *Zamioides* P. Bertrand from the Upper Westphalian beds of France (CORSIN, 1928, pp. 227-229; PL. 10, FIGS. 1-4), but my specimen is very much smaller.

In close association with the seed, there is a portion of a pinnule having a distinct midrib from which the secondary veins, also quite thick, arise at an angle of about 45° bifurcating at least once. It is possible that this seed was borne on the foliage just described, but there is no organic connection.

25. *Cordaicarpus* sp.

Pl. 5, Figs. 56–59

Two small seeds of *Cordaicarpus* type have been found. They are very small, preserved as flat elliptic-ovate impressions, with a broadly pointed apex and a broad rounded base, about 5 mm. long and 4 mm. wide. The surface appears quite smooth. They have a narrow rim representing the sclerotesta, about 0·4 mm. broad along the margin, and widening to about 1 mm. at the apex. In the seed shown in Figs. 57, 58, the rim possesses a fine reticulum (not clearly brought out in the photograph), which may be due to the vascular system of the integument. In the apical portion the rim (FIG. 59) seems to be differentiated into two parts, separated by a curved ridge.

The rim looks like the flattened sclerotesta and not a wing. This shows that our specimens are a *Cordaicarpus* rather than a *Samaropsis*.

Our specimens are rather similar to the *Cordaicarpus* seeds found in central Shansi (HALLE, 1927 a, pp. 209, 210; PL. 54, FIGS. 15, 16). Unfortunately the photographs of the Shansi specimens are not clear enough for comparison.

26. *Rhynchogonium* sp. *A*.

Pl. 1, Fig. 3 at B ; Pl. 6, Figs. 68-70

The seed is ovate, about 3·6 mm. long and 2·4 mm. broad, with a broad round base and a tapering neck. Its surface is carbonized, with fine longitudinal striations. The apical region possesses a few delicate ribs converging towards the tip.

The specimen shown in Figs. 68, 69 probably represents only the nucule of a seed. Around it there are some carbonized crusts which may be the remains of the sarcotesta.

There seems no doubt that seeds of this form are related to Heer's genus *Rhynchogonium* (HEER, 1876, PL. 5, FIGS. 1-11; SEWARD, 1917, pp. 358-360). Our specimen resembles *R. costatus* Heer (HEER, 1876, PL. 5, FIGS. 6-11; NATHORST, 1914, pp. 24-26; PL. 15, FIGS. 44-51), but is smaller.

A second but incomplete specimen is shown in Fig. 70.

The specimens under the generic name *Rhynchogonium* are generally found in Carboniferous beds. Probably the only named specimen from eastern Asia is *R. permocarbonicum*, described by Jongmans and Gothan (1935, pp. 161-164; PL. 53, FIG. 8) from Sumatra. This seed is for the first time recorded from China.

27. *Rhynchogonium* sp. *B*.

Pl. 5, Figs. 64, 65

This seed is ovate, about 4·4 mm. long and 2·3 mm. broad including the blunt beak. Its beak is slightly oblique, with 2 or 3 broad ribs impressed on the surface. The surface of the seed appears smooth except for some very faint lines which converge to the base of the beak that may represent the vascular bundles.

The seed seems to be represented only by the nucule. Around the nucule, especially over the beak, there is a faint badly preserved, slightly carbonized rim, about 1 mm. wide, which probably represents the sarcotesta. There is also a narrow border round the lower left-hand side of the nucule.

This specimen can be referred to *Rhynchogonium*, as it shows some general resemblance to the seeds figured under this name by Heer (SEWARD, 1917, p. 358), Nathorst (1894, p. 48; PL. 4, FIGS. 7, 8) and Jongmans and Gothan (1935, pp. 161-164; PL. 53, FIG. 8). It also somewhat resembles the specimen figured by Bell (1944, PL. 76, FIG. 5) from a Carboniferous bed in Canada under the generic name *Rhabdocarpus*, but ours is much smaller. The latter genus is not well defined, and includes a miscellaneous collection of seeds. If we adopt the original diagnosis by Berger (SEWARD, 1917, pp. 341-344), the name *Rhabdocarpus* should be restricted to specimens with numerous longitudinal parallel striations, which are not seen in my specimen. So it is safer to put it under *Rhynchogonium*.

28. ?*Boroviczia* sp.

Pl. 6, Figs. 71, 72

The seed here is represented by an impression of a nut-like oblong-oval cast. It is about 3·5×1·5 mm. in size, but the seed is incomplete, the apical portion being absent. Three distinct stout longitudinal ribs radiate downwards from the apex, suggesting that they were continued upwards into a beak which is not preserved. The ridges dissolve out near the base of the seed. No traces of a wing can be seen round the cast. The surface of the nucule is finely marked with longitudinal striations.

It is difficult to identify such an imperfect specimen. It may be compared to *Boroviczia Karpinskii* Zalessky from Lower Carboniferous beds in Russia (SEWARD, 1917, p. 360, FIG. 56 I).

29. ?*Carpolithus* sp.

Pl. 5, Fig. 66

The seed shown in Pl. 5, Fig. 66 is an elongated, nearly symmetrical, oblong body. Its size is very small (about 3 mm. long and 0·7 mm. wide). Its apex is truncated and its base round, but slightly oblique. The surface appears smooth.

It rather resembles *Carpolithus coffeoides* Jongmans & Gothan (1935, p. 166; PL. 53, FIG. 9), but my specimen has a truncated apex and a smaller size.

Plantae Incertae Sedis

30. *Plagiozamites oblongifolius* Halle

Pl. 6, Fig. 73

The specimen shown in Fig. 73 represents the apical portion of what I am inclined to regard as a foliage branch, and the following description is based upon that assumption. It closely resembles the terminal part of a specimen described by Halle from central Shansi (1927 a, p. 227; PL. 60, FIG. 2).

It appears to be a dorsiventral shoot with leaves, arranged alternately in two rows on the flanks of the axis. These leaves arise at an angle of about 50° with the axis and are closely set. The proximal parts of the leaves are imbricate. The shape of the leaves is lanceolate, gradually narrowing to the base and apex. The apex is slightly oblique and rounded. The length of the leaf measures up to 3 cm. in this specimen; but the ratio between length to breadth is about 5:1.

The veins are fine, about 40 per cm., usually parallel with the margin, bifurcate at least twice and meet the margin near or at the apex of the leaf.

31. *Tingia carbonica* (Schenk) Halle
Pl. 6, Figs. 74-76

There are several specimens identical with *Tingia carbonica* Halle from central Shansi.

It appears to be some dorsiventral shoot with straight thick axis *ca.* 3 mm. broad. The leaves in my specimens are in two rows, pressed flat by preservation and arise at an angle of 50°-60°. The leaves are linear-obovate, and attain a length of 4·5 cm. and a breadth about 2 cm. with the base slightly narrowing, attached obliquely, in a sessile manner. A rather characteristic slight twist in the base of the lamina tends to bring the leaves on the two sides of the shoot roughly into a single plane. This feature is closely brought out in Figs. 74-76. The apex of the leaf is truncated, dissected into 5-6 sharp, strap-shaped and pointed teeth attaining one-fifth the length of the leaf (Fig. 76). The veins are fine, parallel, and about 24-30 per cm.

This species seems to have been widely distributed in China (Halle, 1927a) and Korea (Kawasaki, 1931-1934, 1939). In China it was so far found in South Manchuria, Shansi, Honan, Hopei and Hunan. This is the first discovery of the species from the Yunnan province.

32. *A reproductive body*
Pl. 6, Figs. 77, 78

This is an impression (in two counterparts) of a slender axis bearing five linear-lanceolate organs. It is very difficult to judge whether it is a cluster of microsporangia or a cupule with 5 bracts.

Each lanceolate organ measures about 2·5 mm. long and 0·5 mm. broad, and has a well-defined pointed apex and a finely striated surface. A straight medial longitudinal line travels through the whole length of each lanceolate organ; it is slightly raised as a ridge and gives the impression that it may be a vascular bundle.

It resembles very much the synangium of *Telangium* sp. figured by Halle (1937, Pl. 6, Fig. 13). No trace of a seed has been observed and no attempt has been made to prepare spores.

Kawasaki (1934, pp. 216, 217; Pl. 89, Figs. 273-275) has described some similar specimens from Korea under the name *Lagenospermum acutilobum*. In Kawasaki's specimens, however, the bracts are drawn out distally into a long thin appendage. He regards his specimens definitely as cupules and suggests that each cupule enclosed a seed. As there is no clear evidence of a seed, either in his specimens or mine, the reference to the genus *Lagenospermum* must be regarded as very tentative.

33. *Astrocupulites* sp.
Pl. 6, Figs. 79, 80

This is a small and rather curious fragment. At first sight it reminds one of the leaf-sheaths of some Equisetales, but the radiating spines or "teeth" show no trace of a vascular bundle. The narrow, curved inner border from which they spring shows under a strong lens a flat surface with the outlines of small isodiametric cells (Pl. 6, Fig. 80). The fossil seems to be the marginal portion of some unknown fructification, with a number of narrow radiating keel-like or wedge-like rays. Each ray is about 2 mm. long with a flat triangular base about 0·4 mm. wide.

The fossil is comparable to some cupule-like organs of unknown morphological nature described from central Shansi by Halle (1927 a, Pl. 48, Figs. 10, 11) under the new genus *Astrocupulites*. But our specimen is slightly smaller and the rays are narrower and more sharply pointed. Evidently it belongs to a different species, but it seems needless to name it without more complete material. It very closely resembles the radiating keels of the "cupular (?) organs" of a fossil described under the new genus *Koraia* by Oishi, from the Jidô series (Lower Permian) of Korea. His two species,

K. koraiensis (OISHI 1931, pp. 355, 356; FIGS. 1, 1a, 2, 3), and *K. obtusa* (ibid., p. 356, FIGS. 4, 4a), have radiating keels of the same nature as in our specimen, but in our specimen no cupulae are preserved and the size is smaller.

In general, our fossil is closer to the Korean specimens than to *Astrocupulites acuminatus* Halle. I am, however, unable to find much difference between *Koraia* and *Astrocupulites*. Oishi has compared his specimens with *Norinia cucullata* Halle, but it seems to me that the Korean fossils are more close to *Astrocupulites acuminatus* than to *Norinia cucullata* owing to the presence in the latter of numerous radiating and bifurcating veins. Oishi, however, has not mentioned *Astrocupulites* in his paper.

It is quite possible that with fuller knowledge of the plants which bore these cupule-like organs we would be able to recognize several distinct genera, but until we know more about the real nature of these organs it seems advisable to refer them to Halle's *Astrocupulites*, employing this name in the sense of a form genus.

34. *A strobilus of unknown affinity*

Pl. 6, Figs. 81-83

The strobilus shown in Pl. 6, Figs. 81-83 is too badly preserved to be identifiable and it is uncertain whether the scales (here for convenience described as sporophylls) bore sporangia or seeds. It is represented by two counterparts discovered while splitting the shale. The lower part of the strobilus is broken and the general form is unknown. The apex narrows rapidly to a broadly conical dome.

The preserved portion measures about 1·2 cm. in breadth and at least 2 cm. in length (the counterpart has the apex). It possesses a stout central axis, covered by numerous compact sporophylls. The sporophylls are rather long and with pointed apex, arising at a broad angle of about 80° with the axis, except in the terminal part of the "cone" where they arise more obliquely. They bend sharply upward in the middle. There is a suggestion of the presence of a keel in the distal upturned limb of the sporophyll. The sporophylls appear to be spirally arranged on the axis.

In spite of several attempts I have not been able to recover any spores from the specimen.

ANALYSIS OF THE FLORA

It is somewhat difficult to discuss the affinities of fossil from such fragmentary specimens as those described above. In the majority of the plants only generic diagnosis can be made and in several cases even this is not possible.

There are 34 species distributed among the following groups:

Equisetales	3
Sphenophyllales	1
Pteridospermae or ferns	14
Cordaitales	1
Semina gymnospermarum	10
Plantae incertae sedis	5
Total	34

The Equisetales are represented by a few *Annularia*-like leaf-whorls. There is also a leaf or scale-whorl doubtfully regarded as Calamarian, and a few leaves provisionally identified as *Asterphyllites*.

Of the Sphenophyllales there are only a few detached leaves, which probably belong to *Sphenophyllum Thonii* var. *minor* (Sterzel).

The most abundant fossils in the collection are fern-like leaves, some of which are known to be Pteridospermae. They are represented by 5 species of *Sphenopteris* and 9 of *Pecopteris*. Only one species of *Sphenopteris* can be identified with a known Shansi plant, *S. Norinii*. Two are closely comparable with *S. Grabaui* and *S. Gothanii*, the remaining two are too fragmentary to be specifically compared. The genus *Pecopteris* is probably the most common type in this flora. Two species are identical with Shansi plants, viz. *P. Wongii* and *P. arcuata*. One is closely comparable with *P. taiyuanensis* (also from central Shansi). There is one form closely comparable with the European Upper Carboniferous species, *P. cyathea*. Three species, *P. huichensis*, *P. yunnanensis* and *P. Sahnii*, are new to science; all of them are very distinctive in venation characters which have not been known previously. It is possible that the *Pecopteris* fronds in this collection contain more than three new species but the preservation in these cases is too fragmentary to make the assignation of new names really safe.

The Cordaitales are represented by a few fragmentary leaves, recalling a species of *Poacordaites* described by Jongmans and Gothan from Sumatra.

TABLE I*

Species from	Huiche	Sumatra	Central Shansi			Korea
			Yuehmenkou Series	Lower Shihhotze Series	Upper Shihhotze Series	
Sphenophyllum Thonii var. *minor* Halle	cf.	—	—	+ (?)	+ (?)	+ (*S. Hallei* ?, *S. Thonii* var. *minor* Halle)
Sphenopteris Norinii Halle	+	—	—	—	+	—
Sphenopteris, cf. *Grabaui* Halle	cf.	+	—	+	—	—
Sphenopteris Gothanii Halle	cf.	+	—	+	—	+
Pecopteris taiyuanensis Halle	cf.	+ (*P.* cf. *Cistii*)	—	+	—	—
Pecopteris Wongii Halle	+	—	—	+	—	—
Pecopteris arcuata Halle	+	—	—	+	+	—
Pecopteris yunnanensis sp. nov.	+	+ (*P. polymorpha*)	—	—	—	+ (*P. polymorpha*)
Cordaites sp.	+	+ (*Poacordaites*) sp.	—	—	—	—
Plagiozamites oblongifolius Halle	+	—	—	+	+	—
Tingia carbonica Halle	+	—	—	+	—	+
Tobleria minor sp. nov.	+	+ (*Tobleria bicuspis*)	—	—	—	—
Cordaicarpus sp.	+	—	—	+ (*C.* sp.)	+ (*C.* sp.)	—
Rhynchogonium sp.	++	+ (*R. permocarbonicum*)	—	—	—	—

* The occurrence of the identical species is marked with a plus sign, and of similar forms with a plus sign followed by the name of the similar species within parentheses. A minus sign indicates that the species is absent; cf. means that a comparable form is present.

A large number of small detached seeds have been met with. Two of these are here described as new species, *Tobleria minor* and *Cornucarpus huichensis*. The latter is found attached to a Sphenopteroid pinnule. In other cases the affinities of the seeds are not determinable. There are in all present three species of *Cornucarpus* (including *C. huichensis*), two species of *Rhynchogonium*, one species of *Samaropsis*. Two seeds are doubtfully referred to the genera *Boroviczia* and *Carpolithus*. The genera *Tobleria* and *Rhynchogonium* are for the first time recorded from China. *Tobleria* is a characteristic fossil of the Sumatra flora and provides an additional link between the *Gigantopteris* flora of Sumatra and of China and Korea.

Among the " Plantae incertae sedis " are two Shansi species, highly characteristic of the *Gigantopteris* flora, viz. *Plagiozamites oblongifolius* and *Tingia carbonica*. There is also one very doubtful specimen represented by a portion of a badly preserved strobilus.

GEOLOGICAL AGE AND RELATIONSHIPS OF THE FLORA

Although the collection does not include any species of *Gigantopteris*, it is obvious from the above description that in the present collection we are dealing with representatives of the *Gigantopteris* flora. Table I shows the distribution, in the *Gigantopteris* floras of other areas, of genera and species which are either identical with or closely related to those here described.

Age of the Huiche Flora — From the framentary specimens described above it may be difficult to settle accurately the age of the Huiche flora. But judging

(i) from the general aspect of the vegetation, and

(ii) from the presence in it of several good species common to the Shihhotze Series (i.e. *Sphenopteris Thonii* cf. var. *minor*, *Sphenopteris Norinii*, *Pecopteris Wongii*, *P. arcuata*, *Plagiozamites oblongifolius* and *Tingia*

carbonica) which have been found neither in the Yuehmenkou Series of central Shansi nor in Sumatra.

It can be safely stated that our flora is not younger than Middle Permian and not older than the Stephanian. Gothan and Jongmans (1935, pp. 186-188) and Jongmans (1937, pp. 354, 355) have definitely determined that the Sumatra flora is Late Carboniferous (Stephanian) in age and they correlate it with the Yuehmenkou Series of central Shansi. So that most probably our flora is Lower Permian, and may be correlated with (if not older than) the Lower Shihhotze Series of central Shansi.

This opinion, however, is confirmed in a discussion meeting held by the Geological Society of China in the Geology Department of Peking University on the 9th August 1947. Professor Hsi-Chih Chang of Tsinghua University says that he has been to the fossil locality, and knows that these fossils were collected from the K'uangshanch'ang Coal Series. Stratigraphically, he says, the K' angshanch'ang Coal Series overlies the Maping Limestone (Stephanian) and underlies the Maokou Limestone (Lower Permian). Of which the latter is further overlain by the Omeishan Basalt, and then by the Hsianwei Coal Series (*see* TABLE II). They were formed in a regular geological sequence, except the Hsianwei Coal Series which is likely disconformable with the Omeishan Basalt. Judging from their similar geological successions he further suggests that the K'uangshanch'ang Coal Series is correlated with the Chiashia Coal Series of the Chenghsiung district and the Basal Coal Series of the Hsianwei district. According to his field investigation, *Gigantopteris nicotianaefolia* Schenk has never been found in K'uangshanch'ang, the Chiashia and the Basal Coal Series of Hsianwei, but it is quite abundant in the Hsianwei Coal Series. It seems to him that the latter is correlated with the Upper Shihhotze Series and the former with the Lower (if not lowest) Shihhotze Series of Shansi.

Comparison with Other Gigantopteris Floras, and Some Geological and Palaeogeologic Considerations — Most of the Huiche species have been found in the Shihhotze Series of central Shansi, but there is nothing which could be compared or identified with the specimens from the Yuehmenkou Series. Some of the Huiche forms are closely comparable to species from Sumatra, and a few are identical with or comparable to the Korean species. The flora, on the whole, is distinctly more close to that of central Shansi than to those of other regions. The occurrence of Sumatra type seeds, *Tobleria minor* and *Rhynchogonium* spp. and *Cordaites* sp. accompanied by a profusion of *Sphenopteris* and *Pecopteris*, gives the Huiche flora somewhat of an Upper Carboniferous aspect and definitely strengthens the link between the floras of central Shansi and Sumatra. This supports the idea of Professor Halle (1927 a, p. 288) that " the southern extension of the arctocarboniferous flora is along the general strike of the mountain ranges from Yunnan to Sumatra ".

It is likely that during the Permo-Carboniferous period orogenic movements had already raised areas in south-western China, Indo-China, Malaya and Sumatra into the form of mountain chains with intervening basins in which plant beds were deposited. Both the Sumatran and the K'uangshanch'ang floras represent depositions which may be contemporaneous or might differ slightly in age. As a result of these orogenic movements we have the phenomenon of igneous activity with the formation of the Omeishan Basalt and the intertrappean deposits in the provinces of Szechuan, Kueichow and Yunnan. Orogensis went on, but became more active in Lower and Middle Permian, marking the climax of the worldwide Hercynian movement as also in the Far East. So the K'uangshanch'ang Coal Series

TABLE II*

C. Shansi	Huiche	Chenghsiung	Hsianwei
Upper Shihhotze Series	Hsianwei Coal Series	Hsianwei Coal Series (250 m.)	Hsianwei Coal Series (418 m.)
	Omeishan Basalt (600 m.)	Omeishan Basalt (60-160 m.)	Omeishan Basalt (600 m.)
Lower Shihhotze Series	Maokou Limestone (250 m.)	Yangsin Limestone (350 m.)	Yangsin Limestone (200 m.)
	K'uangshan-ch'ang Coal Series (80 m.)	Chiashia Coal Series	Basal Coal Series
Yuehmenkou Series	Maping Limestone	...	Huanglung Limestone

* Showing correlation of the K'uangshanch'ang Coal Series with the other series found in eastern Yunnan and in central Shansi. (After Hsi-Chih Chang slightly modified.)

found in eastern Yunnan is merely a part of the sedimentary deposits of south China during this period incorporated with the main Palaeozoic coal formation of north China and Korea.

Comparison with European and American Floras—With one exception, namely a specimen doubtfully compared with *Sphenophyllum Thonii* var. *minor*, the present specimens show no relation with the European and American floras.

Relation with Glossopteris Flora of India and Some Palaeogeographic Considerations — The most careful examination of the specimens fails to reveal a single fragment which is specifically identical or even remotely comparable with any members of the Indian *Glossopteris* flora.

It is hardly possible that there was an early Permian land bridge between the two continents, Cathaysia and Gondwanaland, in northern Yunnan, though the temptation is great to suppose the existence of such a connection due to the comparative nearness of Huiche (the known westernmost extension of the *Gigantopteris* region) to the *Glossopteris* province of India, especially in Assam where the eastern limit of the Indian Lower Gondwana at Sadiya is located (*see* MAP ; *see also* FOX, 1934, p. 43). This supports the idea of Professor Halle (1927 b, p. 288 ; 1937 a, p. 239) and of the late Professor Sahni (1935, p. 289; 1936, p. 324) that the peculiar geographical relations of the two floras in these regions may have something to do with the tectonic features.

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EXPLANATION OF PLATES

PLATE 1

1. ? Annularian shoot. × 1.
2. Fragment of a calamarian leaf or scale-whorl. × 3.
3 A. ? *Asterophyllites* leaves. × 7.
3 B. *Rhynchogonium* sp. *A*. × 7.
4. *Sphenophyllum Thonii*, cf. var. *minor* Halle. Segment of a leaf-whorl. × 1.
5. Idem. The same specimen showing the veins near the base of the leaf, merging into a single broad but short midrib. × 4.
6. *Sphenopteris Norinii* Halle. Fragment of a pinna. × 1.
7. Idem. The same specimen enlarged showing the venation. × 4.
8. *Sphenopteris* cf. *Grabaui* Halle. Fragment of a frond. × 1
9. Idem. The same fragment enlarged. × 2.
10. *Sphenopteris* sp. *A*. Fragment of a frond. × 2·5.
11. *Pecopteris* cf. *taiyuanensis* Halle. Fragment of a pinna. × 1.
12. Idem. Counterpart of the specimen in Fig. 11, showing the venation. × 4.

PLATE 2

13-15. *Sphenopteris* sp. *B*. Fragments of pinnae. × 1.
16. Idem. Part of the pinna in Fig. 15 enlarged to show circular black spots on the pinnules. × 5.
17. *Sphenopteris* cf. *Gothanii* Halle. × 1.
18. Idem. Diagrammatic sketch of a leaflet from Fig. 17. × 3.
19. *Pecopteris Wongii* Halle. × 1.
20. Idem. Part of the same pinna enlarged.
21. *Pecopteris huichensis* sp. nov. Sterile pinna. × 1 (*see also* Figs. 26-29, 30 A, 31, 32, 36).
22. Idem. Part of the same pinna enlarged. × 2.
23. Idem. Another pinna. × 1.
24. Idem. Part of the same pinna enlarged. × 5.
25. *Cordaites* sp. Fragment of a leaf. × 1.

PLATE 3

26. *Pecopteris huichensis* sp. nov. Sterile pinna. × 1.
27. Idem. Fertile pinnae, one of which shows a well-preserved tip. × 1.
28. Idem. Fertile pinna. × 1.
29. Idem. Part of the same pinna enlarged. × 4.
30 A. Idem. Another fertile pinna. × 1.
30 B. *Pecopteris arcuata* Halle. × 1 (*see also* Fig. 35).
30 C. *P. Sahnii* sp. nov. × 1 (*see also* Fig. 33).
30 D. Idem. × 1.
31. *P. huichensis* sp. nov. Fertile pinna in 30 A. × 5.
32 A. Idem. Pinna bearing a few fertile pinnules. × 3·5.
32 B. Idem. Tip of a sterile pinna probably from the same frond. × 3·5.
33. *P. Sahnii*. Part of the specimen in Fig. 30 A enlarged. × 5.
34. *P.* sp. *B*. (cf. *P. cyathea*). × 1.
35. *P. arcuata*. Specimen in Fig. 30 A enlarged. × 4.
36. *P. huichensis* sp. nov. Sterile pinna. × 1.

PLATE 4

37. *Pecopteris* sp. *A*. pinna. × 1.
38. Idem. Counterpart of the specimen in Fig. 37. × 5.
39. Idem. Part of the specimen in Fig. 37 enlarged. × 4·5.
40. Idem. Pinna in Fig. 37 enlarged, to show the distribution of the sori. × 25.
41. Idem. Diagrammatic sketch of a sorus marked *x* in Fig. 40. × 25.
42, 43. Idem. Part of the specimen in Fig. 37 greatly enlarged. × 25.
44. *P.* sp. *C*. × 1
45. Idem. Part of Fig. 44 enlarged. × 5.
46. *Pecopteris yunnanensis* sp. nov. × 1.
47. Idem. × 5.

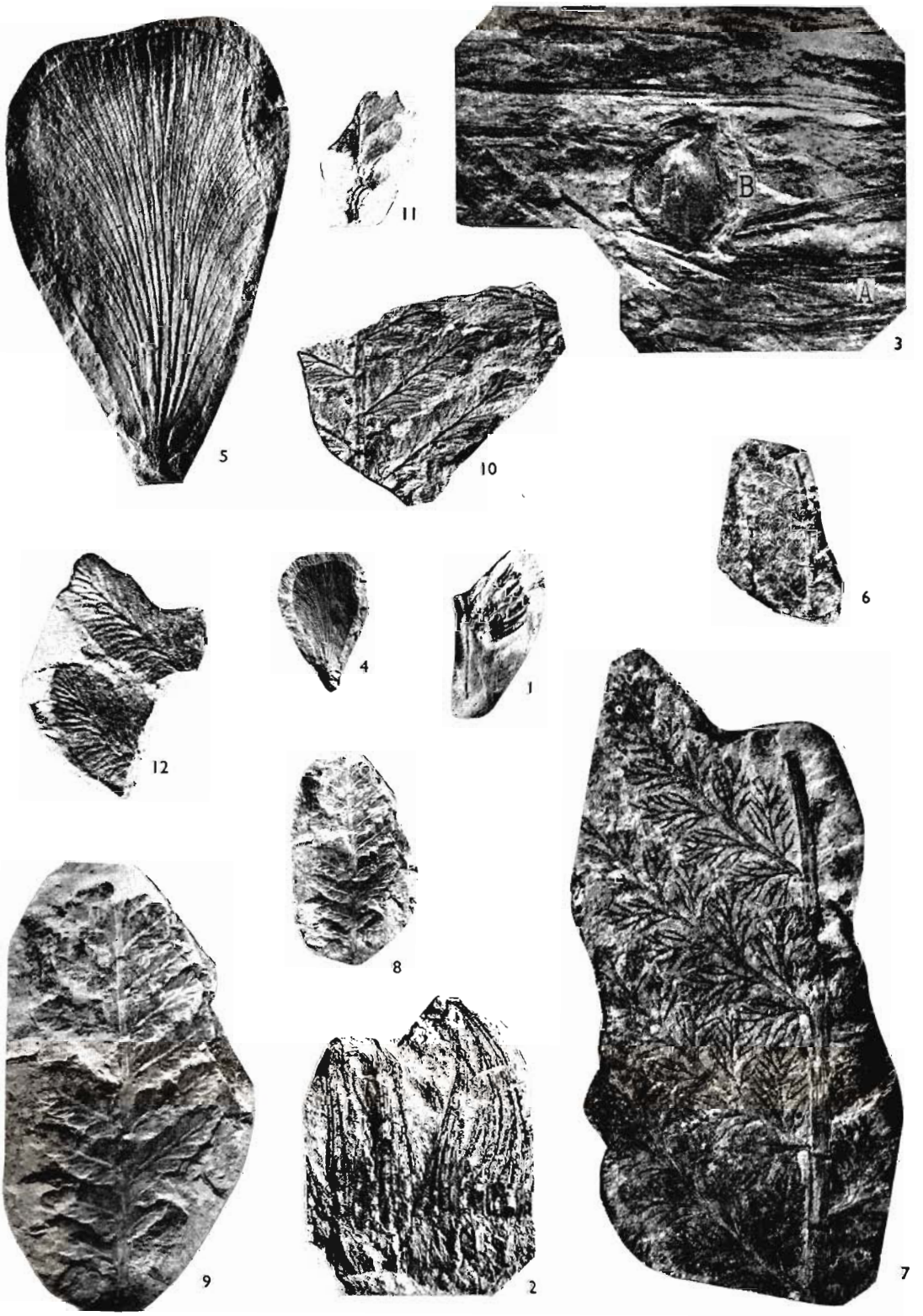
PLATE 5

48. *Tobleria minor* sp. nov. × 12.
49. Idem. Slightly diagrammatic sketch of the same nucules demarcated by a thin round line. × 12.
50. *Cornucarpus huichensis* sp. nov. A seed attached to a sphenopterid frond. × 3.
51. Idem. Slightly diagrammatic sketch of the specimen in Fig. 50. × 10, *c*, small cavity at the apex of the seed, *n*, nucule; *o.m.i.* outer, middle and inner layers respectively of ? wing.
52. ? Idem. Detached seed. × 4.
53. Slightly diagrammatic sketch of the specimen in Fig. 52. × 4.
54. *Samaropsis* sp. × 5.
55. Slightly diagrammatic sketch of counterpart of the above. × 4.
56. *Cordaicarpus* sp. × 5.
57. Idem. Another seed. × 5.
58. Idem. Slightly diagrammatic sketch of Fig. 57. × 5.
59. Idem. Apical part of the seed in Fig. 57 enlarged. × 12.
60. *Cornucarpus* sp. *A*. × 5.

61. Idem. Slightly diagrammatic sketch of Fig. 50. × 5. The dark rim marked *x* round the seed is not a structural part of the seed.
62. *Cornucarpus* sp. *B*. × 5.
63. Idem. Slightly diagrammatic sketch of the same specimen in Fig. 62. × 5.
64. *Rhynchogonium* sp. *B*. × 5.
65. Idem. Slightly diagrammatic sketch of the same specimen. × 5.
66. ? *Carpolithus* sp. × 6.
67 A. *Cordaites* sp. × 1.
67 B. *Samaropsis* sp. × 1.

PLATE 6

68. *Rhynchogonium* sp. *A*. × 5.
69. Idem. Slightly diagrammatic sketch of Fig. 68. × 5.
70. Idem. Another seed. × 5.
71. ? *Boroviczia* sp. × 5.
72. Slightly diagrammatic sketch of the same specimen. × 5.
73. *Plagiozamites oblongifolius* Halle. × 1.
74-76 *Tingia carbonica* (Schenk) Halle. × 1.
77. A reproductive body. × 5.
78. Slightly diagrammatic sketch of the same specimen. × 5.
79. *Astrocupulites* sp. × 5.
80. Idem. Part of the same specimen enlarged, showing the small isodiametric cells on the flat surface of the narrow curved inner border. × 25.
81. A strobilus of unknown affinity. × 3.
82. Idem. Apical part of the same specimen enlarged. × 6·5.
83. Idem. Counterpart of the specimen shown in Fig. 81. × 5.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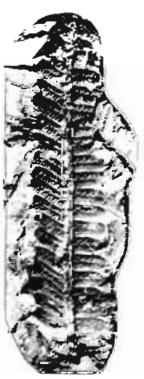

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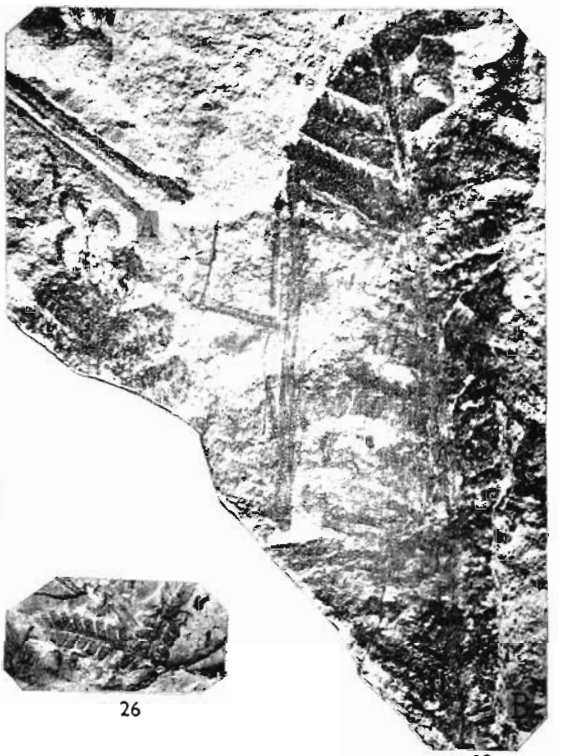

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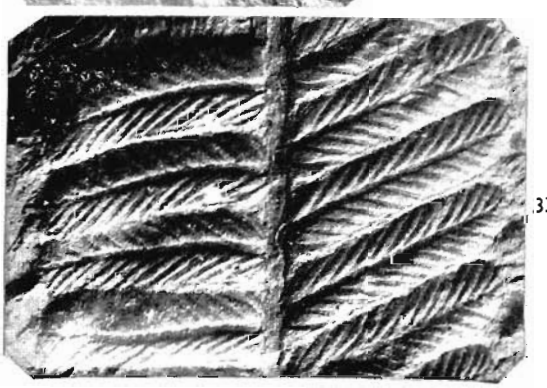

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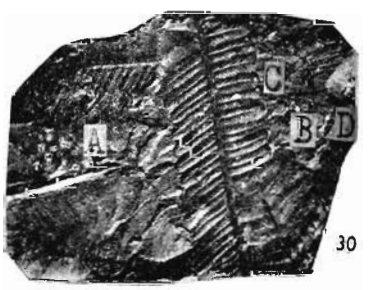

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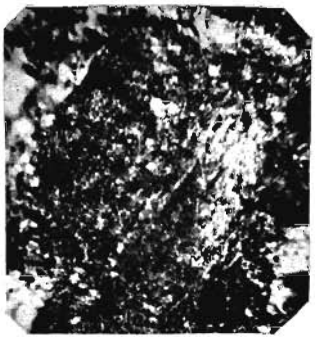

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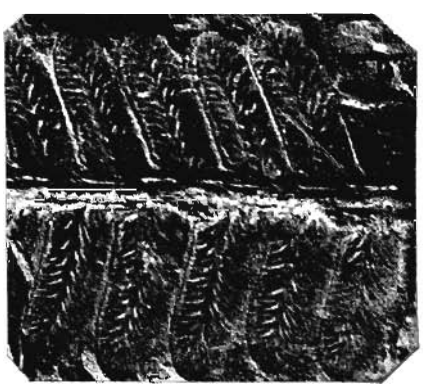

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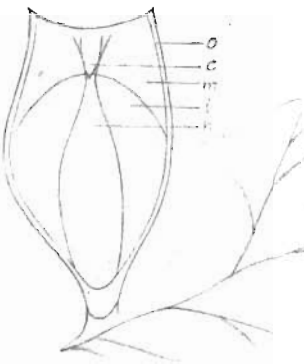

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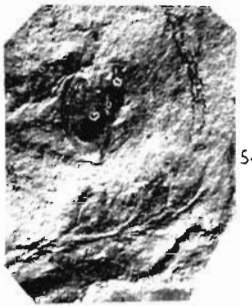

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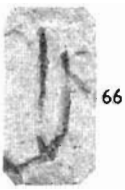

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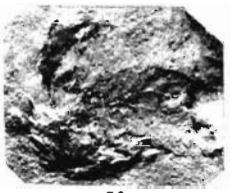

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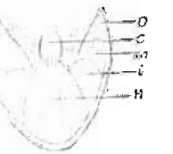

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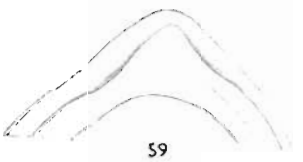

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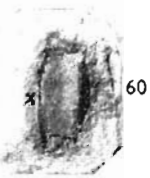

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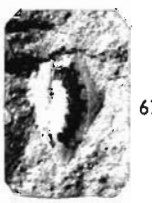

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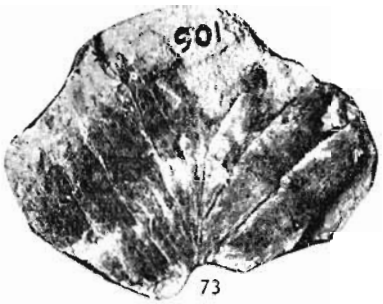

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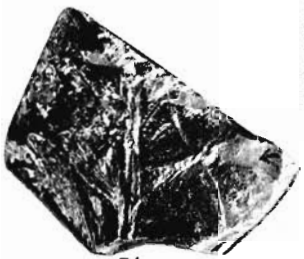
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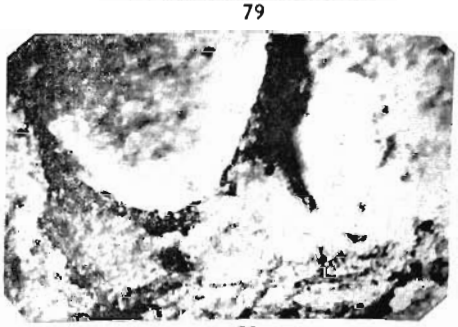
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