A Jurassic species of *Arctobaiera* (Czekanowskiales) with leafy long and dwarf shoots from the Middle Jurassic Yima Formation of Henan, China

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Zhou Zhiyan & Zhang Bole 1996. A Jurassic species of *Arctobaiera* (Czekanowskiales) with leafy long and dwarf shoots from the Middle Jurassic Yima Formation of Henan, China. *Palaeobotanist* **45** : 361-368.

A new species of *Arctobaiera*, *A. renbaoi* is described based on well-preserved long shoots bearing either helically arranged elongate leaves or dwarf shoots with a bundle of elongate leaves and scales at bases, as well as detached leaves. All leaves are sessile with entire lateral margins and veins branched only at the lower part. They vary considerably in shape. Most commonly, they are entire, spathulate or paddle-shaped and with a more or less obtuse apex, but sometimes shallowly or even more deeply bilobed. The leaves are amphistomatic with alternate stomatal and non-stomatal strips on both sides. Stomata are haplocheilic (mostly anomocytic) and monocylic to incomplete dicyclic, consisting of sunken guard cells and normally only slightly thickened subsidiary cells of irregular shape and size.

The new species shows some resemblance with the type-species *A. flettii* Florin, although only dwarf shoots were found in the latter and no anatomical details of leaves and dwarf shoots are known in the present species. The major distinctions between the two species are in the leaf shape and possibly in distribution of stomata. According to Florin, *A. flettii* bears leaves of the hypostomatic type. Comparisons have also been made between the present species with some other ginkgophytic leaf genera. It is believed that *A. renbaoi* is a new member of Czekanowskiales, though its fructification remains unknown.

Key-words—*Arctobaiera*, Czekanowskiales, Middle Jurassic, China.

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सारांश

चीन में हेनान के मध्य जुरेसिक यिमा शैल-समूह से लम्बी पत्तियों एवं छोटे प्ररोह से युक्त *आर्कटोबेयरा* (चेकानोवस्कियेल्स) की एक जाति

झाऊ झियान एवं झाँग बोले

छोटे प्ररोह पर घनी पत्तियों अथवा लम्बे प्ररोह पर घुमावदार रूप में विन्यस्त लम्बी पत्तियों से युक्त सुपरिरक्षित प्रादर्शों पर आधारित *आर्कटोबेयरा* की एक नई जाति–*आ. रेनबाओई* का वर्णन किया गया है। सभी पत्तियाँ पर्णवृन्त विहीन हैं तथा इनके किनारे कटे फटे नहीं हैं। निचले भाग में शिरायें शाखायुक्त हैं। ये सभी आकार में विभिन्नता प्रदर्शित करती हैं। कभी-कभी ये द्विफलकी भी देखने को मिलती हैं। पत्तियों के दोनों ओर रन्ध्र विद्यमान हैं तथा इनमें रक्षक कोशायें दबी हुई हैं तथा सहायक कोशायें आकार में अनियमित हैं।

यह नई जाति प्ररूप जाति–*आ. फ्लीटाई* फ्लोरिन से कुछ समानता प्रदर्शित करती है। यद्यपि इस पूर्व विदित जाति का प्ररोह बौना है तथा इसके शारीरीय लक्षण ज्ञात नहीं हैं। दोनों जातियाँ रन्ध्रों एवं पत्तियों के आधार पर एक दूसरे से भिन्न हैं। फ्लोरिन के अनुसार *आ. फ्लीटाई* में रन्ध्र नीचे की ओर विद्यमान हैं। इसके अतिरिक्त इस जाति की तुलना अन्य गिन्क्गोफाइटी पत्तियों से भी की गई है। ऐसा मत है कि *आ. रेनबाओई* चेकानोवस्कियेल्स का एक नया सदस्य है, हालाँकि इसके फलनों के अवशेष अभी तक नहीं मिले हैं।

SINCE the establishment of the genus *Arctobaiera* in 1936 by Florin from the Lower Cretaceous of Franz-Joseph-Land, no other species besides the genotype *Arctobaiera flettii* has ever been recorded. Recent extensive collections from the Middle Jurassic coal-bearing Yima Formation exposed in the North Open-Cast Mine of Yima Mining Bureau have resulted in finding a new species of this rarely known Mesozoic ginkgophytic genus, which forms the subject of the present article.

The Yima Coalfield is situated at 111°2' - 111°8'E, 34°0'- 34°4'N, in the western part of Henan Province, Central China. The plant-bearing strata uncovered in the North Open-Cast Mine belong to the middle and lower parts of the Middle Jurassic Yima Formation. The present material was collected from a pale-grey thick- bedded to massive siltstone in the middle part of the formation, equivalent to the middle part of Bed 6 in the section of the Yima Formation published in 1989 by the present writers (Zhou & Zhang, 1989, p. 115, text-figure 1), and being below the horizons yielding *Ginkgo yimaensis, Baiera hallei* and *Yimaia recurva* (Zhou & Zhang, 1989a, 1992). In total, there are 12 specimens of this new species including a couterpart in the collection. They occur in a pure stand, no other plants found in the same bed. From 1988, a number of palaeobotanical articles have been published on the fossil plants collected in the same coal mine (Zhou & Zhang, 1988, 1989a, b; 1992; Yao *et al.* 1989), and in these works the stratigraphy and the geological age of the formation were dealt with time and hence are not repeated here. For further information on these subjects, the readers are referred to the above mentioned papers as well as Chang (1965), Wang (1983), Kang *et al.* (1984) and Yang (1994).

DESCRIPTION

Genus—*Arctobaiera* Florin 1936

As it will be discussed below, the new species referred to this genus is generally similar to the type species *A. flettii* Florin and is mainly in accordance with the generic diagnosis given by Florin (1936, pp. 118-119). There are, however, two major characters which are either unknown in, or not in complete agreement with those of the type species. The long shoots with helically arranged leaves were unknown in this genus before, and the stomatal distribution of leaves in the new species is also different from that in *A. flettii* as mentioned in the original diagnosis of this genus. If our attribution of the Chinese species to the genus *Arctobaiera* is correct, the original diagnosis needs, therefore, slight emendment as follows (freely translated from the German text published by Florin (1936); the words in italic being newly added, those in quotation marks deleted):

Emended diagnosis—Foliage leaves without a clean-cut abscissed base, borne either in a helix directly on long shoots or in cluster on dwarf shoots with simple leaf traces and enclosed with single veined scale leaves at the base, linear to tongue-shaped, entire and round at the apex or divided into 2 small lobes as well, narrowing towards the base to almost petiole-like, "hypostomatic and" traversed by many nearly parallel veins originated with repeated bifurcating. In the broadest part of foliage leaves, usually 6-8, up to 10-20 veins present. Bifurcations occurring only along the leaf margins. Lower or both sides of foliage leaves with parallel stomatal strips between non-stomatal longitudinal zones of epidermis running above and below the veins. Stomatal apparatus of the haplocheilic-type, monocyclic or incomplete amphicyclic (dicyclic). Guard cells of the gymnosperm-type, probably without lignified laminae on the ventral walls. Lateral walls of epidermal cells slightly undulate. Vascular bundles collateral endarch and always enclosed with a continuous sclerenchymatous sheath. Secretory cavities absent.

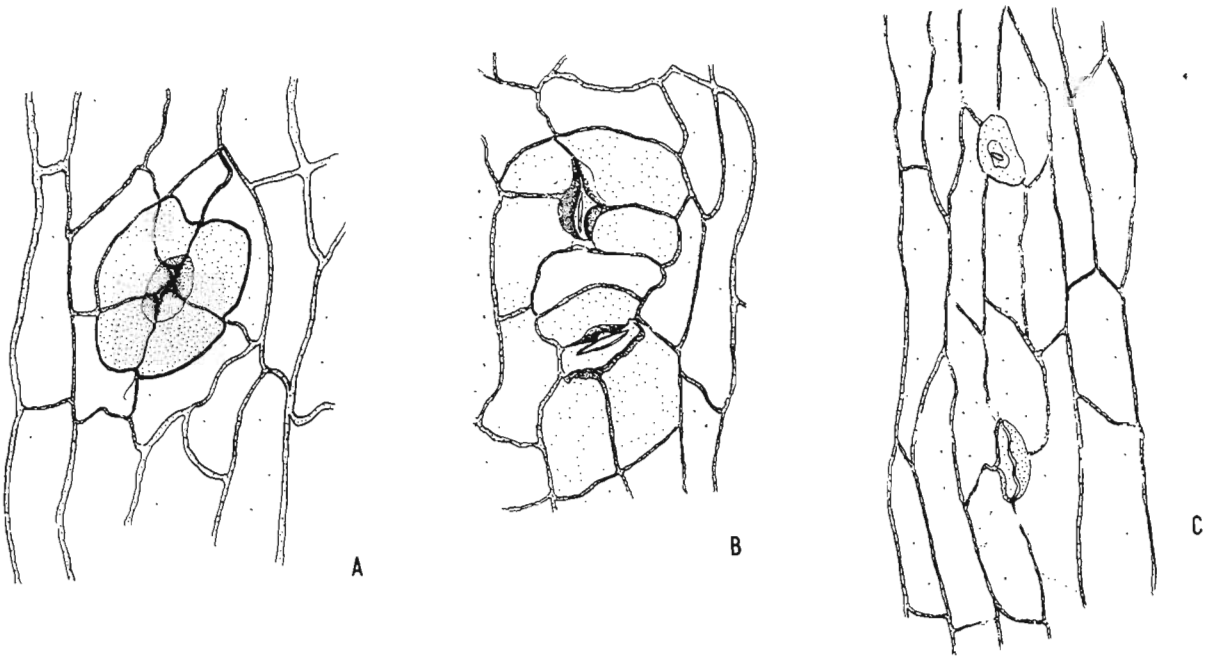
Type species—*Arctobaiera flettii* Florin.

Text-figure 1—Uppermost part of the Holotype, showing a tuft of leaves which are shorter and wider than the ordinary elongate leaves on the dwarf shoots, and one of them with a notched or shallowly , bilobed apex, x 3.

Arctobaiera renbaoi sp. nov.

Pl. 1, figs 1-6; Pl. 2, figs 1-8; Text-figures 1-2

Diagnosis—Leaves attached either in a helix directly to the long shoot or in bundle of up to 4 or more on the dwarf shoot, ranging in form from entire to deeply bilobed; those predominant ones being oblanceolate, paddle-shaped or spathulate in size, with a subrounded, obtusely pointed, retuse, notched or shallowly divided apex, and an entire,



Text-figure 2—A. A stoma on the upper cuticle of the Holotype, showing very narrow pit mouth; **B**. Two stomata on the lower cuticle of the Holotype, one of the encircling cells of the lower stoma being the subsidiary cells of the upper one; **C**. Showing the nearly unspecialized subsidiary cells with very slightly thicker periclinal walls as compared with the ordinary cells; all x ca. 750.

wavy or denticulate distal margins. Veins branched in the lower part of the leaf, but parallel and 0.3-0.5 mm apart in the upper part, ending separately and occasionally each entering into a denticle. Interstitial ribs present.

Leaf amphistomatic, but upper cuticle slightly thicker, and with more coarsely mottled surface and sparser stomata; alternate stomatal and non-stomatal strips present in both cuticles, but sometimes less distinct in the upper one. Epidermal cells rectangular and arranged in regular longitudinal files in non-stomatal strip, larger and more or less irregular in stomatal strips, with microscopically uneven periclinal walls and straight to slightly wavy anticlinal walls. Stomata 1-4 in number in the width of the stomatal strip, usually forming short files of 1-5 and separated from one another, randomly but predominantly longitudinally oriented, elliptical, elongate or nearly isodiametrical, rather irregular in contour. Guard cells sunken, only a small part weekly cutinized. Subsidiary cells irregular in shape and size, 4-5 (-7) in number (0-2 of them polar, the others lateral), with the periclinal wall usually only slightly thicker than that of ordinary epidermal cells, and thickened proximal margins sometimes connected laterally to form a rim surrounding the pit mouth. Encircling cells present, but rarely forming a complete ring; polar ones being more commonly encountered. Stomatal pit mouths rather small, usually rectangular, elliptical or polygonal in the lower cuticle, but slit-like or even closed in the upper cuticle.

Holotype—PB17451 (Pl. 1, fig. 1), counterpart PB17452 (not figured).

Paratypes—PB17449-17450,17453-17454.

Repository—Nanjing Institute of Geology and Palaeontology, Academia Sinica, Nanjing, China.

Type locality—North Open-Cast Mine, Yima City of Henan Province.

Stratigraphical horizon—Middle part of the Yima Formation, Middle Jurassic.

Distribution—At present known only from the type locality and horizon.

Etymology—The specific name *renbaoi* is named in honour of Mr Zhang Renbao, a meritorius collector of fossil plants from the Yima Mine.

Description—The longest shoot in the collection (Pl. 1, fig. 1) attains a width of 3 mm and a length of 170 mm without being complete. It bears 14 or 15 helically arranged dwarf shoots with elongate leaves,

and a loose tuft of shorter and broader leaves at the apex (Pl. 1, fig. 1; Text-figure 1). The dwarf shoots are 1.5-2 mm wide, enclosed with basal scales of about 2 mm long. The elongate leaves are up to 4 in a bundle on the top of the dwarf shoot. They are sessile, oblanceolate, paddle-shaped or spathulate, 30-38 mm long and (4-) 5-6 (-8) mm wide at the widest part in the upper part of leaves, tapering rather rapidly to the apex, but narrowing gradually towards the base; the lateral margins are entire. Leaf apices are subrounded, obtusely pointed, occasionally retuse or notched. The apical margins are nearly entire or wavy. The leaf bases are narrow and petiole-like, about 1 mm wide near the attached point. The venation is not distinct and the number of veins at the leaf base is unknown. The veins repeatedly branched in the lower part of leaves, being unbranched and parallel with one another in the upper part where they are 2-3 per mm. They are very slightly convergent towards the apex, but end separately. Interstitial ribs are present. The shorter leaves at the apex of the long shoot (Pl. 1, fig. 1; Text-figure 1) are generally similar to those elongate ones. They attain a width of 4-6 mm in the upper part. They are cuneiform, obovate and with a retuse to notched apex.

The specimen in Plate 1, figure 2 represents a young shoot with helically attached elongate leaves. The axis is more than 150 mm long and about 3.5 mm wide at the broken lower end. The leaves are considerably different in size, ranging from 12-40 mm long and 2-9 mm wide at the widest part. In shape and venation, they are generally similar to one another, and to those on the dwarf shoots in the above-mentioned specimen. The specimen in Plate 1, figure 4 is a fragment of long shoot with a few elongate leaves still attached. The leaves are of the same general shape as those elongate ones described in the two above-mentioned specimens, but larger in size, up to 48 mm long and 9 mm wide at the widest part. In one of the leaves, the apex is notched or very shallowly bilobed and with a denticulate margin (Pl. 2, fig. 1).

The two isolated leaves above and below in Plate 2, figure 2 are on the same slab and oriented in a direction as if they were attached to the same shoot. The leaf below differs almost in no respect from the well-developed leaves on the shoot in Plate 1, figure 2, but with a distinct shallowly bilobed apex. The leaf above is deeply bilobed, though it is almost indistinguished in venation and general shape and size from the below one. All these detached leaves have only a broken lower end, without a distinct abscissed base.

At first glance, these specimens seem to belong to different plants. There are, however, transitional forms between the predominant undivided leaves and the deeply divided leaves, though some are detached and others are attached to dwarf shoots or directly to the long shoot. Moreover, leaves of quite different shape and size may sometimes be found to occur on the same long shoot or even on the same dwarf shoot (Pl. 1, fig. 5). The most important evidence for the attribution of these different specimens to the same plant comes from the cuticular structure, all leaves being generally similar to one another in this respect.

The different characters of cuticle may vary in measurement as follows (all in μm if not otherwise stated) :

	Upper cuticle	Lower cuticle
Thickness of cuticle	2.5-3.5	1.5-2.5
Width of stomatal strips	350-400	250-300
Width of non-stomatal strips	(100-)150(-200)	120-150
Thickness of anticlinal walls	1.5-3.5	about 1
Size of epidermal cells	(15-)80-120(-210) x (6-)10-25(-50)	
Size of stomata	(50-)80(-125) x (60-)65-90(-160)	
Stomatal density (per mm^2)	12-36	36-58

Besides, trivial distinctions can also be detected in the arrangement of stomata and in the cutinization of the cell walls. In the upper cuticle, the anticlinal epidermal cell walls may be thickened in the non-stomatal strip or near the leaf margin to form irregular longitudinal ridges. Although stomata are normally distant from one another, sometimes adjacent stomata abutt against each other with subsidiary cells

PLATE 1 →

1. Longest shoot in the collection showing 14-15 helically arranged leafy dwarf shoots and a tuft of individual leaves at the top. Holotype PB17451.
2. Shoot with loosely helically arranged elongate leaves. PB17453.
3, 6. Two leaves enlarged from the Holotype and its counterpart (PB17451 & 17452) respectively, showing leaf shape and venation, both x 3.
4. Shoot with large elongate leaves. PB17454.
5. Part of the counterpart of Holotype, showing a dwarf shoot on the right bearing both ordinary long and narrow leaves and a shorter and wider leaf (upper right, arrow) with retuse apex, x 2.5.

PLATE 1

(Pl. 2, figs 3, 6) or share one or two subsidiary cells, or occasionally take encircling cells of adjacent stomata as subsidiary cells (Text-figure 2B). Obviously, none of these are of taxonomic importance.

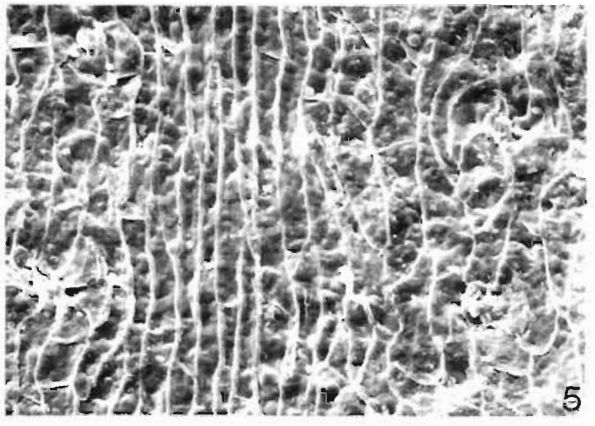
Comparison and discussion—It appears unreasonable to refer the present form to the form-genus *Sphenobaiera* Florin. Although some species may include both bilobed and entire (or nearly entire) leaves, such as *S. boeggildiana* (Harris, 1935; Lundblad, 1959), *S. gyron* Harris et Millington (1974) and possibly *S. nipponica* (Kimura & Tsujii, 1984), divided leaves are predominant in that genus. Only very few species of *Sphenobaiera,* moreover, are known to bear leaves on shoots (Harris, 1935; Kräusel, 1943; Yang, 1986). The overwhelming majority includes only detached leaves with cleanly abscissed bases. *Sphenarion* Harris et Millington is also different from the present form in the repeatedly bifurcated leaves. According to Samylina and Kiritchkova (1991, 1993), it may be a synonym of *Czekanowskia* Heer. From *Pseudotorellia* Florin, the present form is easily distinguished by the cuticular structure. There is indeed a close resemblance in shape between the present undivided leaves and those referred to *Eretmophyllum* Thomas. However, according to Harris and Millington (1974), leaves of *Eretmophyllum* are petiolate and usually larger in size, and though many were seen, not one is attached to dwarf shoot. It is also not known that this genus include such leaves as those of the present form in Plate 2, figure 2. Kimura and Sekido (1965) found the leaves of *Eretmophyllum tetoriense* still attached to a fairly long shoot and believed that they are conspecific with those associated, isolated bilobed leaves referred to *Ginkgoidium nathorstii*, but there is no evidence of cuticular structure for such an assumption.

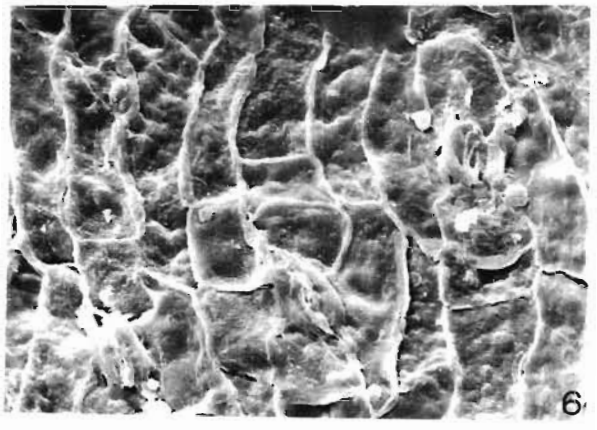
In respect of the persistent leaves in bundle on the dwarf shoot, the present form is similar to *Phoenicopsis* (Heer, 1876; Samylina, 1972), but differs markedly in leaf shape. There is no linear or ribbon-shaped leaves in the material. Evidently, the present form can not be included in *Schmeissneria* Kirchner et Van Konijnenburg-Van Cittert (1994), because the fructification is not known and the leaves are considerably different. *Karkenia* is easily distinguished from the present form by having female fructifications and the predominant divided leaves of the *Ginkgoites*- and *Sphenobaiera*-type (Archangelsky, 1965; Krassilov, 1970, 1972). Undivided leaves are only occasionally known in that genus (viz., *K. hauptmannii* Kirchner et Van Konijnenburg-Van Cittert, 1995).

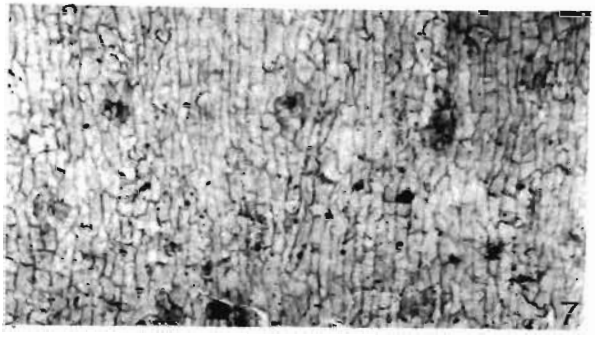
The present form to some extant resembles *Arctobaiera flettii* Florin (1936), despite that they are preserved in rather different ways. The anatomical details of leaves and dwarf shoots are unknown in the present form, while long shoots with helically arranged leaves were not found in *A. flettii.* In general, particularly in leaf cuticular structure and in bearing both entire and bilobed leaves, however, the two forms are generally identical. Besides, the difference in leaf shape, the major distinction between them is that leaves of *A. flettii* are believed to be of hypostomatic type, though Florin did not describe and figure the upper cuticle properly. This feature is indeed useful in identifying some genera (such as *Pseudotorellia*), but it does not seem to be a universally accepted criterion for generic separation in ginkgophytes. Some genera, such as *Phoenicopsis* (Samylina, 1972) and *Ginkgoites* (or *Ginkgo* according to Harris & Millington, 1974), do include both hypostomatic and amphistomatic leaves. It is, therefore, reasonable to include the present form in the genus *Arctobaiera* though there is no doubt that it is specifically distinct from *Arctobaiera flettii.* According to Manum *et al.* (1991), the specimens described as *Arctobaiera* sp. from the Mesozoic of Norway belong, in fact, to a new species of *Ginkgo: G. dahlii.* The specimens described by Lebedev (1974) and Kimura and Sekido (1978) as *Arctobaiera flettii* and

PLATE 2 →

1. Showing a shallowly bilobed apex with denticulate margin, from Pl. 1, fig.4, x 5.
2. Two isolated leaves above and below on the same slab, with shallowly and more deeply bilobed apices. PB17449.
3. Two stomata on the lower cuticle abutting against each other with subsidiary cells which are only slightly darker in colour than the ordinary epidermal cells, from the Holotype, x 500.
4. Two stomata on the lower cuticle, showing narrow or even closed pit mouths, from the Holotype, x 500.
5. Inner side of lower cuticle, showing a non-stomatal strip(middle) between two stomatal strips, and epidermal cell surfaces being rugged, from the Holotype, scanning micrograph x 200.
6. Four stomata more or less crowded in arrangement from the lower cuticle of the Holotype, scanning micrograph x 400.
7. Upper cuticle from the Holotype, x 77.5.
8. Lower cuticle, from the Holotype, x 77.5.







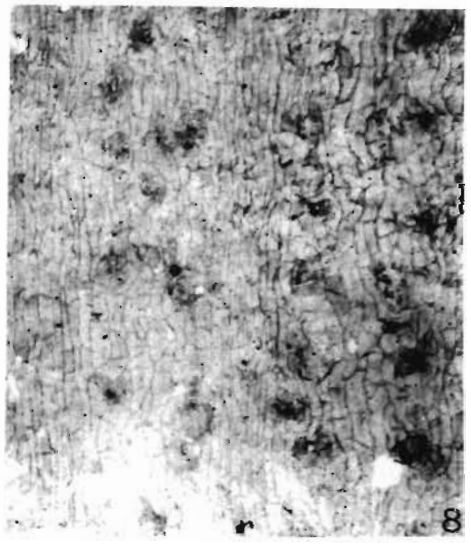


PLATE 2

Arctobaiera? sp. respectively are also different from the present species.

The type species of the genus *Baiguophyllum, B. lijianum* Duan 1987 recorded from the Middle Jurassic of the Western Hills of Beijing differs almost in no important respects from *Arctobaiera flettii* and the present species. Its undivided leaves show a general resemblance to those of the present species, though more narrow and linear in shape. Unfortunately, the material which forms the basis for establishing the new genus is unsatisfactorily preserved. The leaf cuticle remains unknown and there are no divided leaves of the *Sphenobaiera*-type as those found in *A. flettii* and the present species. It is not unlikely that *Baiguophyllum* may prove to be a junior synonym of *Arctobaiera* when more specimens are found and studied, notwithstanding that *B. lijianum* Duan appears to be a separated species. In general gross morphology and amphistomatic cuticles, there is a resemblance between leaves of *Eretmoglossa* Barale 1981 and the entire, elongate ones of the present form. The leaves of the former genus, however, contain resin bodies. They are more narrow and never divided.

The present species is believed to be a new member of Czekanowskiales (Krassilov, 1970, 1972; Harris & Miller, 1974), though its fructification remains still unknown. The absence of resin bodies in the leaves and a clean-cut abscissed leaf base appears to conform such an inference.

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