SPHENOBAIERA IKORFATENSIS (SEWARD) FLORIN FROM THE LOWER CRETACEOUS OF HUOLINHE, EASTERN INNER MONGOLIA, CHINA

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ABSTRACT. *Sphenobaiera ikorfatensis* (Seward) Florin from the Lower Cretaceous Huolinhe Formation in the Huolinhe coal-mining area, eastern Inner Mongolia, China, is identified, described and figured. Comparison with the type material of *Sphenobaiera ikorfatensis* (Seward) Florin from West Greenland confirms its identity. About 20 Chinese leaf specimens are known with well preserved cuticle which is closely similar to the Greenland leaves but more papillate. The palaeoclimatic and phytogeographic significance of the occurrence of this species is discussed in relation to the suggestion that West Greenland, north-east China and eastern Siberia were in the same phytogeographic region during the Lower Cretaceous.

KEY WORDS: *Sphenobaiera*, Ginkgoales, Lower Cretaceous, Mongolia, China, palaeogeography.

SPHENOBAIERA IKORFATENSIS (Seward) type material from the Lower Cretaceous at Ikorfat in West Greenland (Seward 1926) has been diagnosed and redescribed by Lydon *et al.* (2003 – this issue). It has thus been possible to make direct comparison with Chinese material which was previously only tentatively attributed to the species (Sun *et al.* 1995). The material from Greenland and China is clearly identical, as are specimens described from eastern Siberia, Russia, by Samylina (1956, 1963), Krassilov (1972) and Kiritchkova (1985). The Chinese material is known from many more, better preserved specimens than from the type locality and is briefly described below as an addition to our knowledge of this species.

The flora from Huolinhe, Inner Mongolia, is typical of the northern palaeofloristic region of China (indicated in Text-figure 2; see also Sun *et al*. 1995, p. 414, text-fig. 9-1) and includes about 60 species belonging to 36 genera associated with *S. ikorfatensis* (Sun *et al*. 1995). The fossil plants identified in the formation include the following characteristically 'northern' taxa: *Acanthopteris gothanii*, *Coniopteris burejensis*, *C. arctica*, *Onychiopsis elongata* (ferns attributed to the Dicksoniaceae), *Cladophlebis acuta* (fern of the Osmundaceae); *Ginkgo coriacea*, *Sphenobaiera uninervis* (Ginkgoales); *Phoenicopsis* (*Culgoweria*) *jus'huaensis*, *P.* (*C.*) *huolinheiana* (Czekanowskiales); *Schizolepis cretaceus*, *Podozamites* spp. (conifers).

MATERIAL AND OCCURRENCE

Sphenobaiera ikorfatensis was collected by Sun and colleagues (Sun *et al*. 1995) as part of the varied flora from the Lower Cretaceous Huolinhe Formation in the Huolinhe coal-mining area, eastern Inner Mongolia, China. The coal-bearing Huolinhe Formation is composed of siltstones and mudstones intercalated by coal-layers. More than 20 leaf compression specimens of *S. ikorfatensis* were collected, ten of which have well-preserved cuticle. They are housed in the Nanjing Institute of Geology and Palaeontology, with specimen numbers prefixed H.

The cuticle of the specimens is exceptionally well preserved and easy to prepare. The material responds well to oxidative maceration in Schulze's solution, yielding large sheets of cuticle such as in Plate 2, figure 1.

SYSTEMATIC PALAEONTOLOGY

GINKGOALES

Genus SPHENOBAIERA Florin emend. Harris and Millington, 1974

Type species. Baiera spectabilis Nathorst, 1906.

Sphenobaiera ikorfatensis (Seward) Florin, 1936

Plates 1–2; Text-figures 1–2.

1995 *Sphenobaiera ikorfatensis* (Seward); Sun *et al*. p. 417, pl. 104, figs 1–2.

Description. Two specimens of *S. ikorfatensis* material from the Huolinhe Formation were reported and figured by Sun *et al.* (1995, p. 417, pl. 104, figs 1–2) in a general introduction on the Early Cretaceous floras of China, but without detailed descriptions of the two specimens or of the cuticle characteristics of the species. It is now quite clear that the gross morphology and cuticular anatomy of the specimens from the Lower Cretaceous of Huolinhe, China, compare very closely to those of the type specimen from the Lower Cretaceous of West Greenland and the Chinese material is now described and figured here with confidence as *S. ikorfatensis* (Seward) Florin (Seward 1926). All the cuticular characters of the Chinese leaves are in general agreement with those from Greenland, except that the Chinese leaves seem to be more strongly cutinized than the two known Greenland leaves (Lydon *et al.* 2003) and the stomatal and other cell dimensions tend to be at the larger end of the known range.

Plate 1 shows six of the wedge-shaped leaves of *S. ikorfatensis*, up to at least 13–14 cm long and deeply divided into 4–6 strap-shaped segments with the median division deeper than the lateral dichotomies. It is clear from the leaves in Plate 1, figures 1 and 3 that the leaves must have reached in excess of 15 cm in length, both being incomplete at the tips. Some of the smaller leaves (Pl. 1, figs 5–6) show narrowing near the apex to a blunt tip. The leaf segments are about 1 cm at the widest with straight, narrow veins occurring at a density of 2–3 per mm (Text-fig. 1A–B). Frequently occurring resin bodies are spindle-shaped (Pl. 2, fig. 9), about 1–2 mm long by 0·5 mm wide or less.

Plate 2 and Text-figure 1 show the cuticle of Chinese *S. ikorfatensis* to be closely comparable to that of the type material, though rather better preserved than in the leaves from Greenland (see Lydon *et al.* 2003). Both are amphistomatic leaves with similar vein density and numerous resin bodies, the main epidermal features of close similarity being as follows: stomata on upper surface avoiding veins, sparse, with orientation mainly, but not strictly, longitudinal (Text-fig. 1A); stomatal apparatus on upper surface rounded in outline with wide stomatal pit surrounding exposed guard cells (Text-fig. 1C; Pl. 2, fig. 2); stomata on lower surface numerous, avoiding veins, overwhelming majority longitudinally orientated (Text-fig. 1B); stomatal apparatus of lower surface narrowly oval in outline (Text-fig. 1D); guard cells have strong, radiating cuticular striations at the edges of the dorsal plate (Pl. 2, fig. 7).

Discussion. Specimens described as *S. ikorfatensis* f. *papillata* from the Aldan River and Bureja basins by Samylina (1956, 1965; Krassilov 1972), and as *S. ikorfatensis* by Kiritchkova (1985) from the Lena River, eastern Siberia (see Text-fig. 2), are now also known to agree with the type specimen from West Greenland, both in gross and anatomical characters. Samylina (1965, p.100) indicated that the epidermal cells of the material from Aldan are characterized by prominent cuticular thickenings and papillae which were then 'absent' in the type material described by Seward (1926). However, on the basis of the detailed anatomical study by Lydon *et al.* (2003) of the type specimen of *S. ikorfatensis*, showing closely similar cuticle characters, the designation 'forma papillata' is no longer necessary for the Russian specimens.

There are numerous *Sphenobaiera* specimens from the Lower Cretaceous of north-east China which have previously been identified as *S. longifolia* (Pomel) Florin. The type material of this species occurs in the Jurassic of France, and it has also been described from the Middle Jurassic flora of Yorkshire, England

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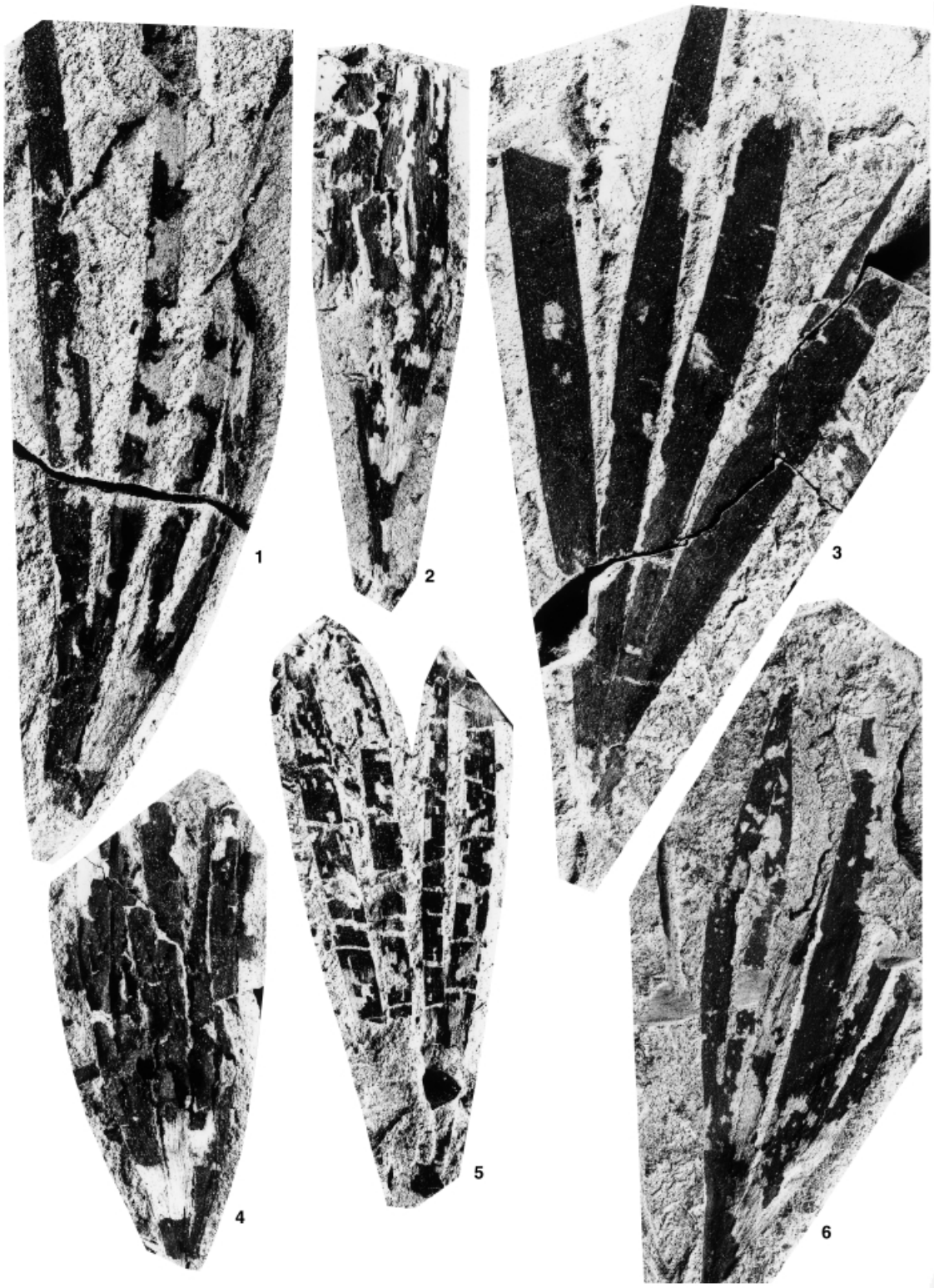
EXPLANATION OF PLATE 1

Figs 1–6. *Sphenobaiera ikorfatensis* (Seward) Florin from the Lower Cretaceous Huolinhe Formation, eastern Inner Mongolia, China. Selection of well-preserved leaves showing the deep dissection into strap-shaped divisions. 1, H198; 2, H193; 3, H190; 4, H189A; 5, H199; 6, H191. All ×1.

PLATE 1



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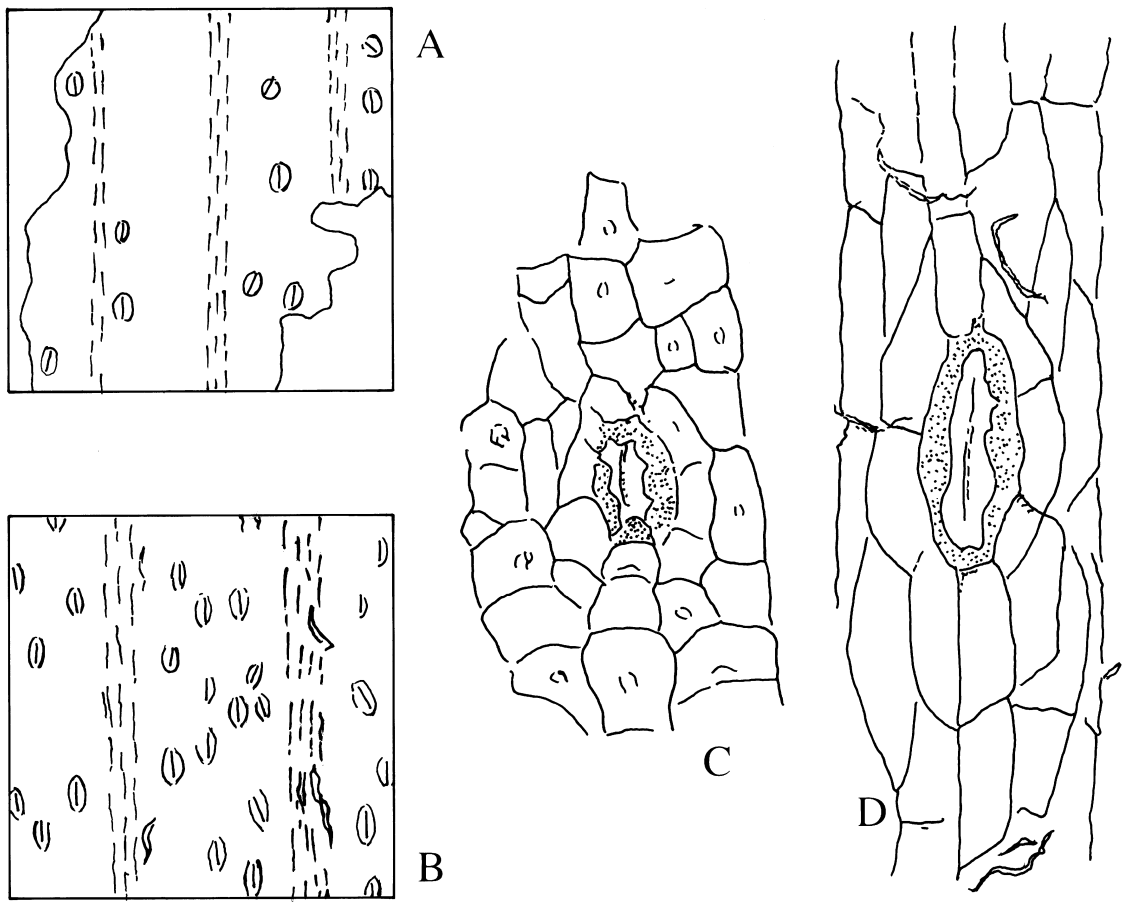
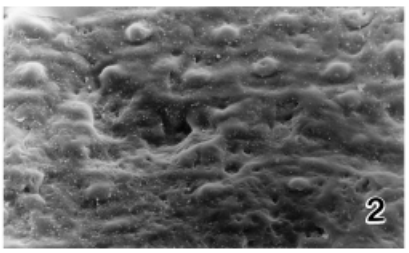
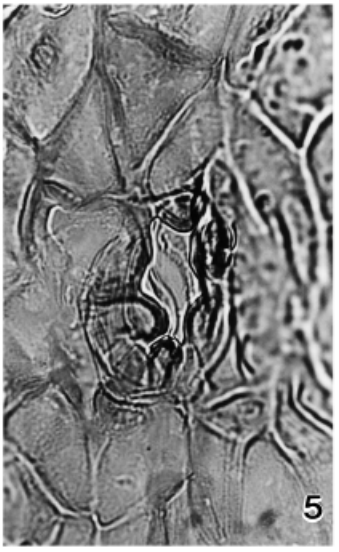


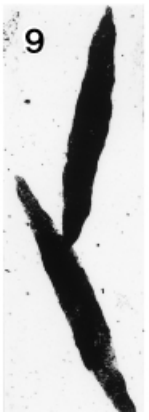
TEXT-FIG. 1. A–D, cuticle of *Sphenobaiera ikorfatensis* (Seward) Florin; all H189–2B. A, upper cuticle showing positions of three veins (dashed lines) and sparse scattering of stomata in intervein areas; ×50. B, lower cuticle showing positions of two veins and numerous stomata in intervein areas; ×50. C, upper cuticle showing a single stomatal apparatus with rounded outline and wide stomatal pit; ×250. D, lower cuticle showing a single stomatal apparatus with narrowly oval outline and elongate ordinary epidermal cells in longitudinal files; ×500.

EXPLANATION OF PLATE 2

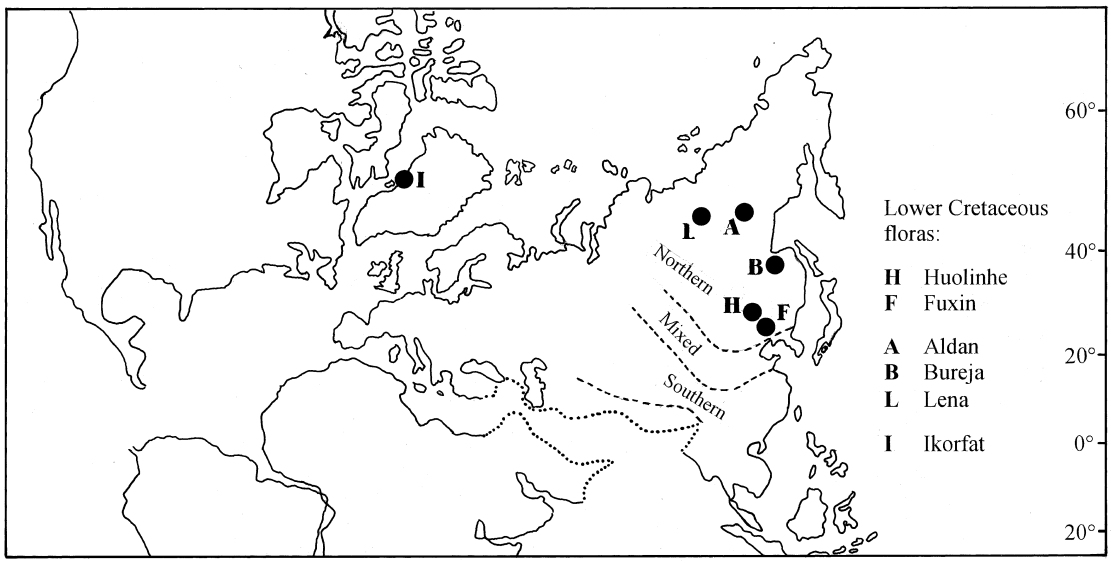
Figs 1–9. *Sphenobaiera ikorfatensis* (Seward) Florin from the Lower Cretaceous Huolinhe Formation, eastern Mongolia, China. 1, cuticle of upper surface showing stomata in areas on either side of a vein; H190-1; ×125. 2, outer surface of upper cuticle in SEM showing stomatal pit with lobed rim and papillae on ordinary epidermal cells; H191-5; ×250. 3, inner surface of same cuticle preparation as 2 showing openings to hollow papillae; ×250. 4, upper cuticle in LM showing papillate ordinary epidermal cells; H190-1; ×250. 5, cuticle of upper surface in LM showing single stomatal apparatus with lobes of subsidiary cells forming rim of stomatal pit; H190-1; ×500. 6, SEM, outside view of single stoma on lower surface showing elongate, lobed pit rim surrounding exposed upper surface of guard cells; H190-1; ×1000. 7, inner view of single stoma from lower surface with striate margins of the dorsal plates of the guard cells and thick cutinisation of subsidiary cells; H190-2; ×750. 8, SEM, outside view of leaf cuticle showing longitudinal cuticular ridges marking files of cells at leaf margin, upper surface on left, lower surface on right; H190-1; ×250. 9, two spindle-shaped resin bodies isolated from leaf; H190-1; ×15.







GE *et al.*, *Sphenobaiera*



TEXT-FIG. 2. Palaeogeographic map of the Early Cretaceous Northern Hemisphere, showing localities from which *Sphenobaiera ikorfatensis* (Seward) has been identified; Huolinhe, Inner Mongolia, China; Fuxin, north-east China; Aldan River, Bureja Basin, Lena River Basin, eastern Siberia; Ikorfat, West Greenland. See text for discussion of the Southern, Northern (= Siberian-Canadian) and Mixed floristic regions of China. (Adapted from Hughes 1976, p. 39, fig. 5.1 and Sun *et al.* 1995, p. 414, text-fig. 9-1).

(Harris and Millington 1974, p. 44). Morphologically, *Sphenobaiera ikorfatensis* is rather different from *S. longifolia* in having wider leaf segments and the cuticle also differs (Lydon *et al.* 2003). In the light of the present study it seems very likely that the specimens described as *S. longifolia* from the Lower Cretaceous Fuxin Formation of Fuxin, north-east China by Chen *et al.* (1988, p. 70, pl. 43, figs 3–6; pl. 44, figs 1–3) also belong to *S. ikorfatensis*. This locality is, therefore, tentatively included on the palaeogeographic map in Text-figure 2, showing the known distribution of the species.

PALAEOCLIMATIC AND PALAEOPHYTOGEOGRAPHIC SIGNIFICANCE

Palaeogeographically the Lower Cretaceous floras from eastern Siberia and eastern Mongolia, in which *Sphenobaiera ikorfatensis* has now been positively identified, are attributed to the Siberian-Canadian floristic region of Vachrameev (1991; Sun 1993). During the Early Cretaceous these floras possessed the same 'Siberian-type' plants in common, being especially abundant in Ginkgoales, Czekanowskiales and deciduous needle-leaf conifers, together with cycads and robust ferns including those attributable to the Dicksoniaceae, Osmundaceae and Gleicheniaceae. Indications are that the Lower Cretaceous floras of western Greenland (Seward 1926) also belong to the Canadian-Siberian floristic region, though Vachrameev (1991, p. 130) considered these floras to be of a more southerly type. *Sphenobaiera,* as well as other ginkgoalean genera (e.g. *Ginkgoites, Ginkgo*), all of which have thick cuticles, have usually been considered as indicators for the palaeoclimatic reconstruction of the Mesozoic. Features such as obvious growth-rings, which occur in some of the woody fossils from the Huolinhe Formation, provide supporting evidence. These characteristic plants are considered to indicate moderate temperatures and humid, seasonal climates in the northern–north-eastern Eurasian landmass (Vachrameev 1991; Sun 1993, 1995; Sun *et al.* 1995), including north-east China, and now apparently including western Greenland during the Early Cretaceous.

The floras of the Canadian-Siberian type usually contrast quite sharply with those of the European-Chinese (Euro-Sinian) floristic region of Vachrameev (1981; Sun 1993) which, with a dearth of

Ginkgoales and Czekanowskiales, are characterised by abundant Bennettitales, Cheirolepidiaceae and other scale-leaf conifers, together with ferns of the Schizaeaceae and Matoniaceae. The fern *Weichselia* occurs in most of the Lower Cretaceous low-latitude floras worldwide, commonly as fusain (= fossil charcoal), and is widely regarded as a climatic indicator (e.g. Watson and Alvin 1996). These rich Mesozoic assemblages are thought to be indicative of subtropical–tropical palaeoclimates (Kimura 1987; Vachrameev 1991) with the Wealden, the oldest Cretaceous flora, often cited as a classic example (Vachrameev 1991, p. 130; Sun *et al*. 1995, p. 415). However, recent findings indicate that this comparison might not be as valid as hitherto considered.

Since the work of Vachrameev established the two major floral provinces (Vachrameev 1991) Sun (1995) has recognised in the Lower Cretaceous of China a zone in which both northern and southern floral elements occur. Text-figure 2 shows this 'Mixed' floristic belt which is discussed and figured in more detail by Sun *et al*. (1995, p. 471, text-fig. 9-1). Recently, the Wealden flora in England, long thought to be poor in northern elements, has been shown to have considerable numbers of ginkgoalean, czekanowskialean and deciduous needle-conifer species (Watson *et al*. 2001) and in addition an increased number of cycads (Watson and Cusack in prep.). In the light of this, it is perhaps more appropriate to compare the Wealden with Sun's mixed zone. In China the evidence strongly suggests a warm, arid climate moving northwards with the invasion of southern plant elements, soon to be joined by angiosperms in the latter part of the Early Cretaceous. No such palaeoclimatic evidence is yet available for the Wealden and the significance of the recently discovered 'northern element' remains under consideration. It is now clear that Vachrameev's floristic regions are somewhat oversimplified and that they will continue to be refined as our knowledge of Lower Cretaceous floras increases.

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