

***In situ* reproductive organs of Early Cretaceous ferns from Northeast China**

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FILICOPSIDA is a predominant group of the Early Cretaceous floras of Northeast China, which approximates 100 species and accounts for more than one third of the floras. The majority of this group are of great importance and significance in stratigraphy. The previous studies of these ferns are mainly morphological^[1-5], with only a few concerning the *in situ* spores and sporangia^[6, 7]. In recent years, the authors have carried out a research project on the *in situ* reproductive organs of the Early Cretaceous ferns from 7 basins of Inner Mongolia, Liaoning, Jilin and Heilongjiang of Northeast China. The study focuses on 35 species of 17 genera belonging to 10 families. The present note briefly introduces the results of this study by listing some representative species.

1 Trilete spore ferns

About 18 species of 10 genera have been proved to be trilete spore ferns by *in situ* spore analysis, which are assigned to Schizaeaceae, Dicksoniaceae, Osmundaceae, Adiantaceae and Hymenophyllaceae. Another 10 species are assigned to this type. The reproductive organs of trilete spore ferns are mainly characterized by sori rounded, elliptical or linear and apically, marginally, abaxially borne on the veins or scattered over the abaxial surface of the pinnules; indusia cup-like, bivalvate or as an intermedium of these two types and sometimes the sporangia covered by unicellular trichomes. For some genera, the annuli are unknown. The sporangia are bucket-like or spherical, sessile or with a short stalk. The annuli are apically circular, oblique or vertical, generally consisting of more than 20 thickened cells. The spore output of the sporangia ranges from several dozens to several hundred. The spores are trilete, triangular to subtriangular in polar view, commonly sculptured except those of Dicksoniaceae (Plate I-3—7).

1.1 Schizaeaceae

Ruffordia goepperti (Dunk.) Seward is the only schizaeaceous fern found from the Lower Cretaceous of Northeast China. The sporangia buckle-like in shape, possibly with a short stalk, abaxially scattered on the contracted fertile pinnules, covered by trichomes when younger and exposed when mature. The annuli apical, complete, composed of 17—25 thickened cells (Plate I-4), with a distal plate in the top center of the sporangium. The spore output of the sporangia ranging from 48 to 500 and inversely proportional to the size of the spores. The spores trilete, rounded triangular in polar view, with cicatricose to canaliculate sculptures (Plate I-7).

Ruffordia goepperti is close to the extant *Anemia* of Schizaeaceae in sporangia and spores, which indicates that it undoubtedly belongs to Schizaeaceae. Compared with the disperse spores, the *in situ* spores of *Ruffordia goepperti* are identical with *Cicatricosisporites australiensis* and *C. minor*. *C. australiensis* represents the ripe spore and *C. minor* represents the young one.

1.2 Dicksoniaceae

The Dicksoniaceae includes 10 species under genera *Dicksonia*, *Acanthopteris* and *Coniopteris*. The sori usually terminally borne on the contracted pinnules. The indusia of the three genera different from each other: *Dicksonia* with a bivalvate indusium, *Coniopteris* with a cup-like indusium, while *Acanthopteris* with an intermediate type between them, the upper part of the indusium cracked and the lower part continued. The sporangia spherical, the annuli nearly vertical and composed of about 25 thickened cells, with 64 spores per sporangium. The spores trilete, triangular or subtriangular in polar view. Among the 10 studied species, only the spores of *Acanthopteris gothani* are sculptured with granulae of 0.5—1 μm in diameter, and spores of the others such as *Dicksonia silapensis*, *Coniopteris setacea*, *C. longipinnata*, *C. huolinensis* are smooth (Plate I-8).

1.3 Hymenophyllaceae

Eogonocormus is a new genus^[5, 8] of Hymenophyllaceae represented by *E. cretaceum* and *E. liaoningensis*. The sori circular, marginally borne on the fan-like fertile pinnule, usually 9—12 sori in a pinnule. Each sorus output thousands of spores. The spores rounded or rounded triangular in polar view, trilete, sculptured with bacula, granules and spinula (Plate

I-3).

2 Monolete spore ferns

About 17 species from 7 genera have been proved to be monolete spore ferns by *in situ* spores analysis and another 8 species possibly belong to this type. Based on the sori, sporangia and spores, they are mainly attributed to Athyriaceae, Dryopteridaceae, Aspleniaceae, Pteridaceae, Polypodiaceae and possibly Thelypteridaceae. The patterns of the reproductive organs of these ferns are advanced. The sori are dorsally borne on the lamina of the pinnules (Plate I-1), usually with indusia. The sporangia are spherical, relatively small in size, with long but slender stalks. The stalk consists of 3 rows of cells. The annuli are vertical and composed of a smaller number of thickened cells, generally 13—16 (Plate I-2, 6), 64 spores per sporangium. The spores are bilateral, monolete, elliptic in polar view, most with smooth exine (Plate I-5).

2.1 Athyriaceae

Six species of *Athyrium* have been described from the Lower Cretaceous of Northeast China^[4, 5, 7]. The sori and indusia of *Athyrium* mainly hoof, hook or crescent shaped, dorsally borne on the later vein, half way to the margins of the pinnule. The sporangia spherical, 64 spores per sporangium. The annuli vertical and composed of 13—16 thickened cells (Plate I-2). Spores bilateral, elliptical in polar view, monolete, exine smooth. The sori and spores of different species are different while the sporangia are rather close to each other in outline and size.

2.2 Dryopteridaceae

Dryopterites, with 3 species described, strongly resembles the extant *Dryopteris* in its sori and indusia. The sori rounded or rounded-reniform, normally dorsal on the later veins, indusia rounded or rounded-reniform and attached by the inner end of the sinus. Sporangia spherical, with a slender stalk, 64 spores per sporangium. The annuli vertical, composed of about 15 thickened cells. The spores bilateral, elliptical in polar view, monolete, exine smooth.

2.3 Aspleniaceae

Among the five studied species of *Asplenium* (belonging to Aspleniaceae), *A. tiefanum* and *A. popovii* have been studied in detail. The sori rectangular or crescent in form, dorsally borne on the later veins. The sporangia spherical, with long slender stalks, 64 spores per sporangium. The annuli vertical, composed of about 16 thickened cells. The spores bilateral, elliptical in polar view, monolete, with smooth exine (Plate I-5).

2.4 Pteridaceae

Arctopteris and *Palibiniopteris* are attributed to the Pteridaceae for the dorsally and marginally borne sori, with hundred of sporangia in a sorus. The sporangia spherical, with stalks. The annuli vertical, of about 14 thickened cells. The spores bilateral, elliptical in polar view, monolete. The exine smooth, tuberculate or granulate.

Approximately 40 species of ferns whose spores have not been discovered are mainly placed in *Cladophlebis*, *Sphenopteris*, *Gleichenites*, *Chiaohoella*. The dorsal sori containing a few sporangia and circular annuli show that *Gleichenites* is similar to the extant Gleicheniaceae but no *in situ* spores have been found. The reproductive organs of *Chiaohoella*,

Cladophlebis and *Sphenopteris* are also unknown. It is likely that most of these ferns should have trilete spores because the palynological studies indicate that the variously sculptured trilete spores dominate the Early Cretaceous palynological assemblages of Northeast China, while those ferns with trilete *in situ* spores have only been found in a smaller number so far.

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