

## Research Advances

## New Discovery of Reproductive Organs and Spores in Situ of Ginkgoales and Czekanowskiales from the Middle Jurassic of Shaanxi, China

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### Objective

Ginkgoales and Czekanowskiales are important components of Mesozoic flora and were widely distributed in the Northern Hemisphere. They are usually preserved together in the stratum. Their fossils are abundant in the Middle Jurassic of Shaanxi Province, but there are no reports on their reproductive organs. Here, we report two male gymnospermous pollen cones from the Middle Jurassic Yan'an Formation of the northeast Yulin City, Shaanxi Province, China. The characteristics of the fossils, including those of pollens, have been described in detail. The new specimens were compared with fossils closely similar in morphology, and the taxonomic affinity and systematics were established. The present results offer new fossil materials for the study of taxonomy, evolution, and phytogeography of Ginkgoales and Czekanowskiales.

### Materials and Methods

The fossil reproductive organs of Ginkgoales and Czekanowskiales were studied, which were preserved by compression, and partly coalification, in mudstone. The specimens were well preserved, and some laminae of microsporophylls in *Sorosaccus gracilis* could be seen. To obtain the detailed morphological features, the specimens were observed under a Zeiss Discovery V20 Stereo Microscope and photographed using a Nikon D90 camera. All specimens have been deposited in the Key Laboratory of Stratigraphy and Paleontology, Institute of Geology, Chinese Academy of Geological Science.

### Results

Based on the morphological characteristics of the fossils and pollens, all specimens were found to belong to two species: *Sorosaccus gracilis* Harris and *Ixostrobus lepidus* (Heer) Harris of the orders Ginkgoales and Czekanowskiales, respectively.

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### 1. Genus *Sorosaccus* Harris, 1935, emend. Liu, Hueber, Li et Wang, 2005

#### *S. gracilis* Harris, Fig. 1a–g.

Male cones are catkin-like, cylindrical or fusiform, erect or slightly curved, tapering toward the top, 32–40 mm long, and 6.9–9.5 mm wide. Each male cone is composed of two parts: the main axis and numerous spirally arranged microsporophylls. The main axis is longitudinally ribbed, 1.4–2 mm in diameter. Microsporophylls are compact, approximately 32 in number, and oblique with the main axis. The distance between the first microsporophyll and the base of the main axis is 6.5–14.6 mm and the distance between neighboring microsporophylls is 1.2–1.6 mm. A microsporophyll consists of petioles and laminae. The laminae are lanceolate, usually falcate, and the visible portion is 1–2 mm long and approximately 0.6 mm wide, and most of the laminae were not preserved. The petioles are invisible, and the lateral and abaxial sides of the petiole bear microsporangia, 3–5 microsporangia comprising a cluster. Microsporangium is oval or nearly rounded in shape, 1–1.2 mm long, and 0.6–1 mm wide. The mature microsporangia dehisce longitudinally into two parts. The pollen grains are boat-shaped; monocolpate type, with wavy edges of colpus; approximately 51.5  $\mu\text{m}$  long in the polar axis and 35.5  $\mu\text{m}$  long in the equatorial axis (Fig. 1h).

### 2. Genus *Ixostrobus* Raciborski, 1892, emend. Harris, 1974

#### *I. lepidus* (Heer) Harris, Fig. 1i–p.

Strobili are long, cylindrical, slightly curved, intact, broken at the base, and at least 47 mm long, 11–15 mm wide, and partly coalified. The main axis of the strobili is up to 2 mm wide and gradually becomes narrow toward the top, bearing sporophylls from the middle to the top. Sporophylls are spirally arranged on the main axis; they are outspreading, slender and loose, 2.5–6.0 mm long, 0.6–1.3 mm wide, and are approximately 26–50 in number. Sporophylls that grow in the middle of the strobili are the longest, becoming shorter toward both ends of the axis,

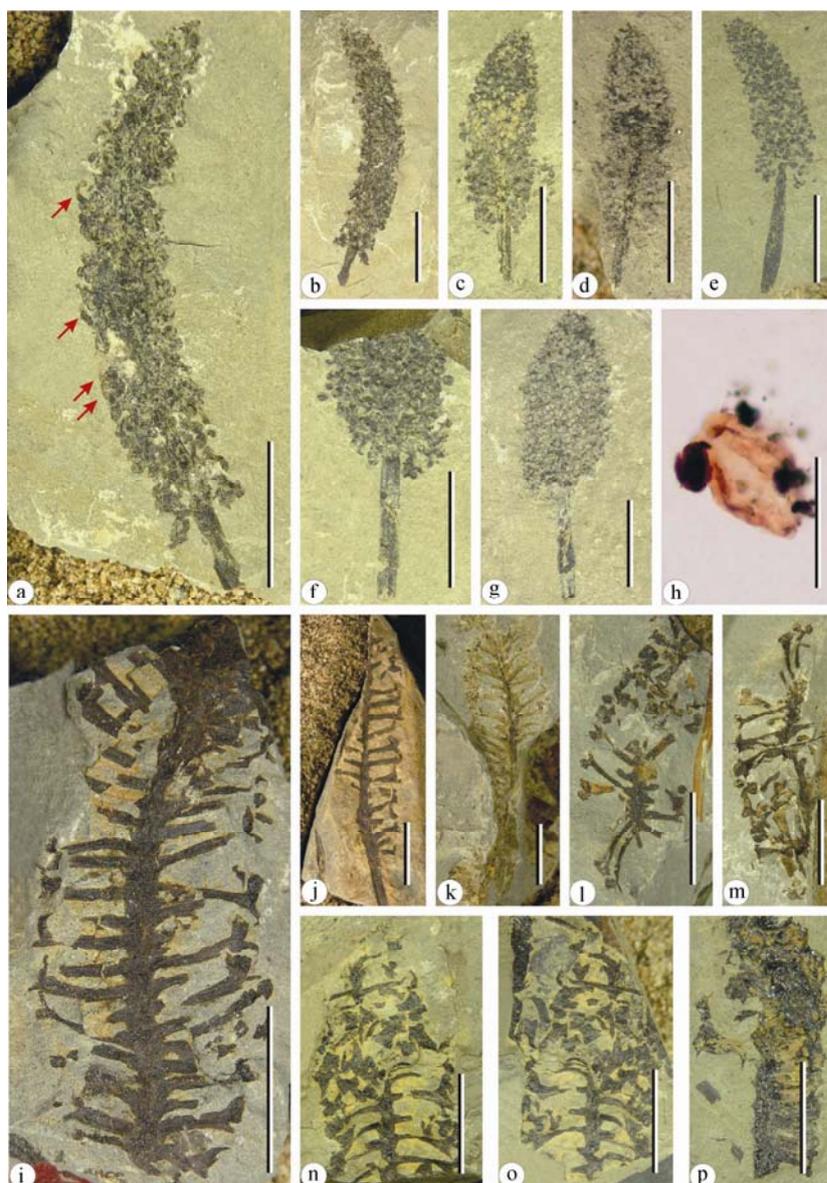


Fig. 1. Reproductive organs of Ginkgoales and Czekanowskiales from Yan'an Formation of Yulin, Shaanxi Province, China. (a–g) *Sorosaccus gracilis* (arrows show the microsporophylls), scale bar=5 mm; (h) the boat-shaped pollen, scale bar=50 μm; (i–p) *Ixostrobus lepidus*, scale bar=5 mm.

and the distance between neighboring sporophylls is approximately 1.5 mm. They are at angle of nearly 90° with the main axis, which decreases toward the top of the strobili. The terminal of the sporophyll broadens, usually bearing 2–3 sporangia.

## Conclusions

This report is the first to identify *Sorosaccus gracilis* and *Ixostrobus lepidus* from the Yan'an Formation in Yulin District and the first to identify pollen grains in situ of *S. gracilis* in China. Based on the stratigraphic age, we concluded that *S. gracilis* from the Middle Jurassic (3–5 microsporangia) may be a transitional type between *S.*

*gracilis* (Late Triassic, 6–8 microsporangia) from the Yangcaogou Formation, Yixian, and *Ginkgo liaoningensis* (Early Cretaceous, 3–4 microsporangia) from the Yixian Formation, Liaoning, in the evolutionary course of the ginkgoalean pollen cones. New discovery of the reproductive organs are very significant in the classification, evolution, and phytogeography study of Ginkgoales and Czekanowskiales.

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