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An Intriguing Half Leaf from the Middle Jurassic of China

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Abstract

Most leaves in angiosperms have reticulate venation, but not all leaves with reticulate venation belong to angiosperms. Although angiosperms flowers have been reported in the Jurassic, leaves similar to angiosperms are lacking in the Jurassic. Here we report an unnamed fossil leaf from the Middle Jurassic Yan'an Formation of Ningxia, China. Although its partial preservation does not allow us to determine the affinity of the fossil, its occurrence underscores the probablity that future digging may uncover angiosperm leaves in the Jurassic.

Keywords: *Fossil, Middle Jurassic, China, Angiosperms, Leaf*

The origin and early evolution of angiosperms, which have more than 300,000 species and account for more than 90% species diversity of land plants, have been foci of botanical debates for long time. Some palaeobotanists thought that angiosperms did not occur on the Earth until the Cretaceous. But recent years witnessed increasing reports of angiosperms in the pre-Cretaceous age. Among the reports, *Schmeissneria* [1,2] and *Nanjinganthus* [3,4], both from the Early Jurassic, are based on tens even hundreds of specimens, making a strong case that angiosperms have long existed in the pre-Cretaceous. Theoretically, angiosperm leaves have more potential to be preserved as fossils. But the fact is that angiosperm leaves are almost completely lacking in the Jurassic. This situation makes any trace of angiosperm-like leaves in the Jurassic especially badly wanted. Here we report a partially preserved leaf from the Yan'an Formation (the Middle Jurassic) of Lingwu, Ningxia, China (37°43'N, 106°26'E, Figure 1). The character assemblage of reticulate venation and intramarginal vein of this leaf are only seen in angiosperms hitherto, making it unique in the fossil record. This discovery makes future discovery of angiosperm leaves in the Jurassic more likely.

The specimen (No. SGY007-16, deposited in Ningxia Geological Museum) was preserved as a compression with some coaly residue, uncovered from the Yan'an Formation (the Middle Jurassic), which is widely distributed in Northeastern China and has yielded various fossil plants [5-8]. The specimen is a grey siltstone slab 36 mm x 26 mm. The details were imaged using a Nikon SMZ1500 stereomicroscope equipped with a Nikon DS-Fi1 digital camera. All figures are organized using a Photoshop 7.0.

The leaf is incomplete, at least 15 mm long, 4 mm wide (Figure 2a). The leaf is smooth-margined, with an intramarginal vein (Figure 2a, 2b and 2d). Lateral veins parallel each other, branching from the midvein at an angle between 40° and 50° (Figure 2a and 2b). Lateral veins and transverse veins in between form angular meshes, which are 0.44-1.22 mm long and 0.2-0.45 mm wide (Figure 2a-2c). Lateral and transverse veins form right angles or acute angles, about 88 μm wide, with no obvious differentiation between lateral and transverse veins (Figure 2a-2c). Rarely, there is a freely-ending veinlet in an areole (Figure 2c).

Other than in angiosperms, reticulate venation has been in several fossil taxa, including ferns (Clathropteridaceae, Dipteridaceae, Polypodiaceae), uncertain group (Gigantopteridales), seed plants (Glossopteridales, Caytoniales, Ginkgoales, Cycadales, Gnetales, angiosperms, uncertain groups) (Table 1). Therefore the occurrence of reticulate venation does not ensure that a taxon with reticulate venation is an angiosperms [9-12].

Our survey of fossil and extant taxa with reticulate venation indicates that, besides the implication given by reticulate venation, the occurrence of intramarginal vein appears to be restricted to angiosperms (Table 1). Therefore the occurrence of intramarginal vein in our new leaf seems to underscore its possibility of an angiosperm. This inference is further strengthened by the occurrence of freely ending veinlet in areole, which, although not strictly restricted to angiosperms, is only seen in angiosperms, Gnetales, and fossil taxa of uncertain affinity. Taking all together, despite its Jurassic age and partial preservation, our new leaf with reticulate venation, intramarginal vein, and freely ending veinlet suggests that, unlike widely-believed, angiosperms are more likely to be a truthful existence in the Jurassic, in line with previous reports of Jurassic flowers [1-4, 13] and implication given by molecular clock studies [14].

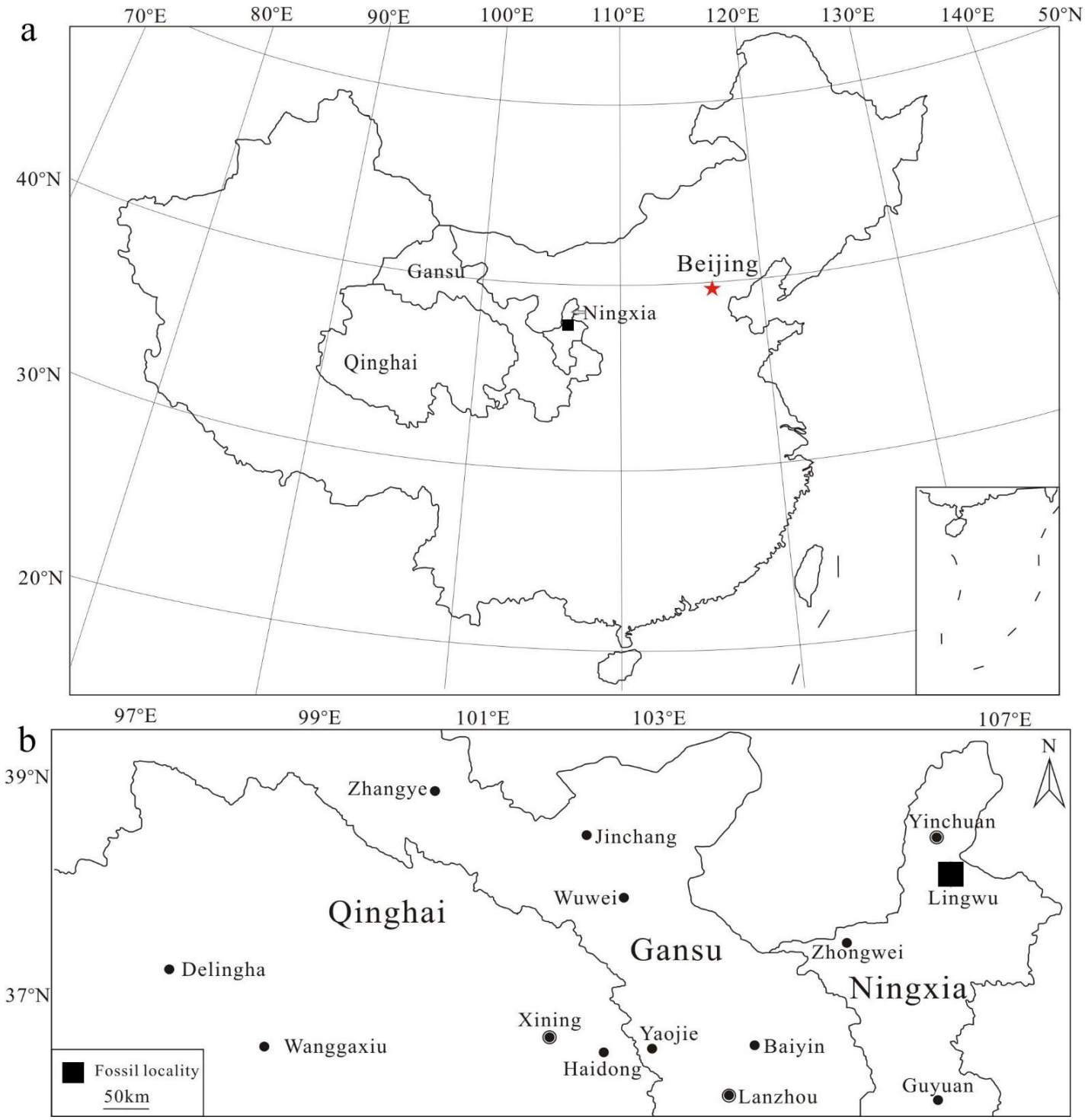

Figure 1: Geographical information of the fossil locality in Lingwu, Ningxia, China (37˚43'N, 106˚26'E). **a.** Fossil locality (black square) in northwestern China. **b.** Detailed position of fossil locality (black square) in Lingwu, Ningxia, China.

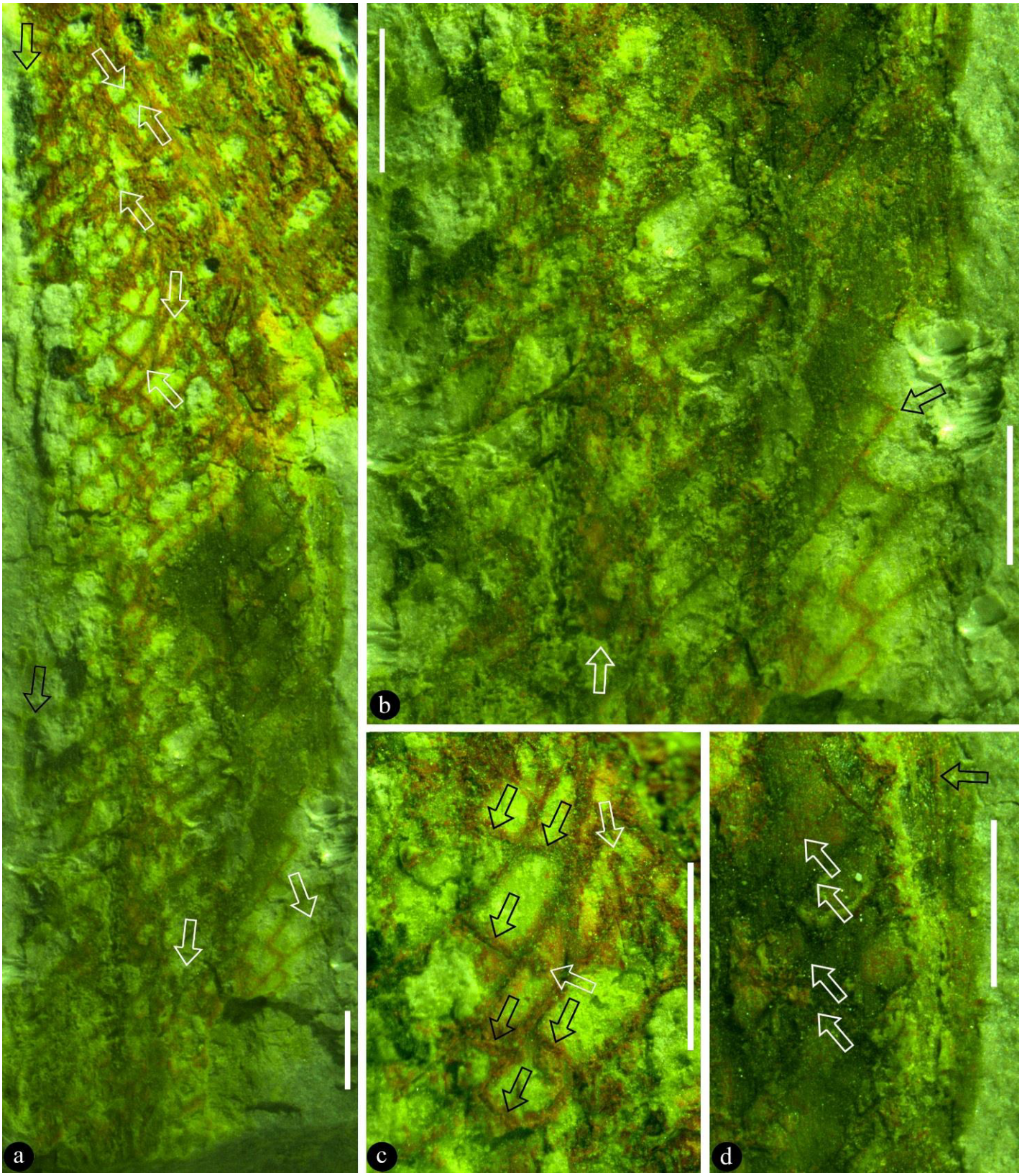

Figure 2: The partially preserved leaf and its details. All scale bar=1 mm. **a.** The general view of the specimen, showing the partial lamina and partially preserved midvein (black arrow) and the freely ending veinlets (white arrows). **b.** Detailed view of the basal portion of the leaf, showing a branch in the background (white arrow) and vein (black arrow) after skeletonization. **c.** Vein meshes after skeletonization, showing the transverse veins (black arrows) between lateral veins. Note the freely ending veinlet (white arrow). **d.** Detailed view showing smooth margin with intramarginal vein (black arrow) and parallel lateral veins (white arrows).

Table 1: Comparison of our leaf and previously reported taxa with reticulate venation. Note that intramarginal vein is restricted to angiosperms.

	Affinity	Margin	Reticulate venation	Intramarginal vein	Vein order	Midrib	Secondary vein	Freely ending veinlet	Age	Ref
Clathropteris	Clathropteridaceae	toothed	frequent	absent	4+	present	unbranched	absent	Mesozoic	
Hausmannia	Dipteridaceae	toothed	frequent	absent	3	absent	dichotomous	absent	Mesozoic	[9]
Polypodium	Polypodiaceae	toothed	frequent	absent	3	present	unbranched	absent	extant	[10]
Woodwardia	Polypodiaceae	smooth	frequent	absent	3?	present	dichotomous	absent	extant	[10]
Onoclea	Polypodiaceae	smooth	frequent	absent	2	present	?	absent	extant	[10]
Linopteris	Seed plants	smooth	frequent	absent	1	present?	dichotomous	absent	Palaeozoic	[10]
Reticulopteris	Seed plants	smooth	frequent	absent	2	present	dichotomous	absent	Palaeozoic	[10]
Lonchopteris	Seed plants	smooth	frequent	absent	2	present	dichotomous	absent	Palaeozoic	[10]
Ginkgo biloba	Ginkgoales		infrequent		1	absent		absent	extant	[10]
Stangeria	Cycadales		frequent		2	multi-strand	dichotomous	absent	extant	[10]
Ctenis	Cycadales		infrequent		1	absent		absent	Mesozic	[10]
Dictyozamites	Bennettitales		frequent		1	absent		absent	Mesozoic	[10]
Drewria	Gnetales		frequent		2	absent	unbranched	absent	Cretaceous	[10]
Welwitschia	Gnetales		frequent		2	absent	unbranched	absent	extant	[10]
Gnetum	Gnetales		frequent		4	multi-strand	dichotomous	simple-branched	extant	[10]
Glossopteris	Glossopteridales	smooth	frequent		2	present	dichotomous	absent	Permian	[10]
Gangamopteris	Glossopteridales	smooth	frequent		1	multistrand	dichotomous	absent	Permian	[10]
Gigantonoclea	Gigantopteridales		frequent		4	multi-strand	unbranched	absent, branched	Permian	[10]
Delnortea	Gigantopteridales		frequent		4	multi-strand	unbranched	absent	Permian	[10]
Sagenopteris	Caytoniales		frequent		2	present	dichotomous	absent	Jurassic	[10]
Sanmiguelia	Uncertain		variable		4	absent	variable	absent	Triassic	[10]
Marcouia	Uncertain		frequent		2	present	dichotomous	absent	Triassic	[10]
Furcula	Uncertain		frequent		3–4	present	excurrent/ dichotomous	present	Triassic	[10]
Pannaulika	Uncertain		frequent		4	present	excurrent	present	Triassic	[10]
Myrtophyllum geinitzii	Angiosperms	smooth	frequent	present	4	present	dichotomous		Cretaceous	[11,12]
Myrtophyllum angustum	Angiosperms			present						[11]
Grevilleophyllum constans	Angiosperms			present						[11]
Eucalyptophyllum oblongifolium	Angiosperms			present						[11]
Eucalyptolaurus depreii	Angiosperms	smooth	frequent	present	3	present	brochidodromous	absent	Cretaceous	[11]
Eucalyptolaurus	Angiosperms	smooth	frequent	present	3	present	brochidodromous	absent	Cretaceous	
Callianthus	Angiosperms	smooth	frequent	present	1	absent	dichotomous	absent	Cretaceous	
Our leaf		smooth	frequent	present	2?	present	unbranched	rare	Jurassic	

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