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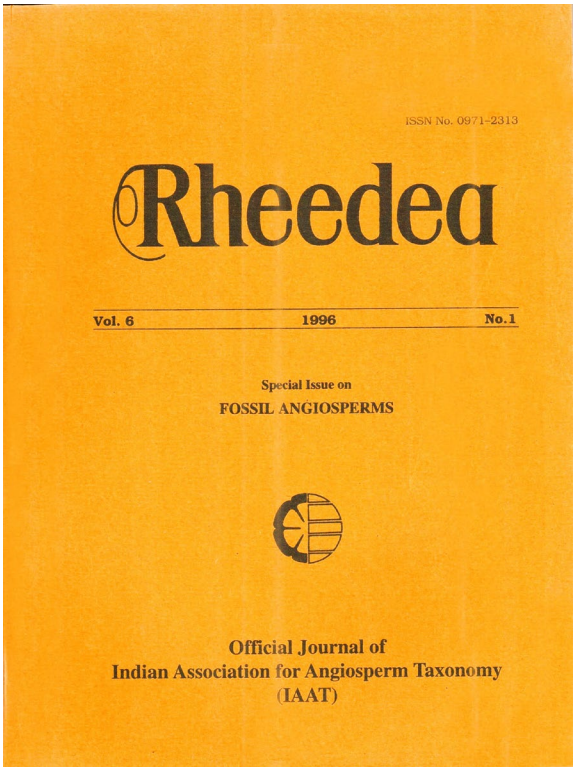

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A new species of *Pterocarya* (Juglandaceae) from Middle Jurassic of Yanliao region, North China

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Abstract

A fossil fructification of *Pterocarya* associated with the Middle Jurassic floras of Eastern Yanliao of North China resembles closely that of the modern species *Pterocarya stenoptera* C. DC. and *P. tonkinensis* (Franch.) Dode, in morphology, structure and habit; and is described as a new species viz., *P. sinoptera* Pan Kuang. It implies that the genus *Pterocarya* varies little from Jurassic to the present, as in similar cases of Jurassic *Paliurus* and *Zizyphus* reported in 1990 from the same fossil flora. It is obvious that Amentiferous and Magnolian taxa had been in China during Middle Jurassic or earlier, showing that *Pterocarya*, or Juglandaceae as a whole, may have originated in North China before Mesozoic.

INTRODUCTION

In a poster (No. 1271) exhibited in 15th IBC, Yokohama, 1993, the fossil Amentiferous plants of Middle Jurassic floras collected from Eastern Yanliao region (Lat. 40° 58' N and Long. 120° 21' E) of North China were reported briefly, in which a fossil fructification of *Pterocarya* of Juglandaceae, labelled as LSJ 00845 (A, B) was also shown. By a kind invitation of Prof. K. S. Manilal, the author reports here in detail the unique fossil fructification of *Pterocarya*, to congragulate Birbal Sahni Institute of Palaeobotany, Lucknow, India, in its Golden Jubilee Year. During the past five decades Professor Birbal Sahni, his successors and many botanists and palaeobotanists of this Institute has made remarkable and praiseworthy contributions.

The Middle Jurassic Floras of the region are predominated by ferns, Equisetales, Bennettitales, Nilssoniales, Cycadales, Ginkgophytes, conifers and Czekanowskiales, but also have a minor component of angiospermous plants and semiangiosperms (Sinodicotiophytes), plants of unknown affinity and a few unrecognized taxa. It was surprising to find that the Jurassic angiosperms have differentiated clearly into dicots and monocots, Magnolian and Amentiferous and woody and herbaceous, with many families and genera (in my collection itself), characterised by such a high evolutionary level similar to that of the Tertiary and modern flowering plants. Among these, the fossils *Paliurus* and *Zizyphus* of Rhamnaceae were described in 1990. The fossil specimens LSJ 00845 (A, B) are preserved by the author.

Fossil records of *Pterocarya* are scanty. Those described are largely in leaflets and fruits, without inflorescence or fructification, occurring mainly in the Tertiary strata in Eastern

Asia, Western Siberia and Europe. Two forms of fossil leaflets are reported from China. The one from Upper Miocene to Lower Pliocene of Yunnan has been diagnosed to be of *P. insignis* Rehd. et Wils. The other from Shanwang Formation of Miocene in Shandong was named as *P. serrulata* Hu et Chaney. In Japan two types of fossil leaflets, *P. asymmetrosa* Konno and P. ezoana Tanai et Suzuki, are reported from the Miocene, while *P. asymmetrosa* was considered as closely resembling the modern species *P. rhoifolia* Sieb. et Zucc. Dorofeev (1963) described two types of fruits, *P. crassa* Dorof. and *P. kirrerskina* Dorof. from Oligocene of Western Siberia. All the many fossils found there are preserved in endocarps but, none of their anatomical data are given. In Europe, Chandler (1961) described a fruit, *P. bornorensis* Chandler, from the Palaeocene in Sussex of England and Muller-Stoll and Madel (1960) reported a petrified wood *Pterocaryoxylon pannonicum* from Lower Tertiary of Hungary. The fossil pollen of *Pterocarya* are seldom known. Cronquist (1981) mentioned that according to Wolfe (1973) the pollens referable to *Carya, Juglans* and *Pterocarya* occurred by the end of Paleocene. Apart from these records, there are no fossils of *Pterocarya* known from Cretaceous or earlier geological times. The Jurassic fossil fructification described here may be significant in considering the origin and early evolution of the Amentiferous taxa.

Description and discussion of the fossil

Juglandaceae

Pterocarya Kunth, 1842

Pterocarya sinoptera Pan Kuang, sp. nov. (Figs. 1–3).

Holotype	:	LSJ 00845 B
Repository	:	Laboratory of the Bureau of Coal Geology of Northeast China, Shenyang, P. R. China.
Locality of collection	:	Eastern Yanliao, North China

Material

Specimens LSJ 00845 (A, B) represent the lower part of a spicate fructification. The counter parts A and B represent the fossil remains preserved in the overlying and underlying rocks burying the vegetal fructification. In part A the impressions are formed well and in part B the material of the compression remains. On the same specimen an undetermined samara is preserved near the fructification. Fossil specimens are kept without any processing.

Explanation of Fig. 1. A & B. Counter parts of LSJ 00845 (A, B) of the Jurassic fructification-*Pterocarya sinoptera* sp. nov.: A. part A; B. part B, (x1); C. Impression of the whole fossil on part A (LSJ 00845A), exhibiting the entire aspect of the fructification, (x2); D. An enlarged mould of the lowest (the first, counted in upward sequence) winged nut on the left side of the fructiferous axis, (x15); E. Basal portion of the fructiferous axis with thin ribs and rounded fruit-scars on its surface, (x10).

Figure 1. *Pterocarya sinoptera* Pan Kuang, sp. nov.

Description of the fossil LSJ 00845A (Part A)

The lower part of the spicate fructification is 65 mm long and 25 mm wide. The fructiferous axis is 4–3 mm wide with thin ribs and scars of fruits (nutlets, samaras) on the surface. The winged nuts are arranged densely on the axis. Nuts small, sessile, rhomboidally globular, with apex mucronate and base narrowly rounded and 4–6 mm in diam. Exocarp of the nut ribbed densely, wall of endocarp filled with numerous minute globular cavities, about 120 in one sq. mm, appearing honey-comb like when enlarged. Navel of the nut circular, about 0.5 mm across. Suspected seed (?) impressions appearing in pair inside the mould of nut. Lateral wings of nuts oblong or ovate, 7–10 mm long and 4–6 mm wide, with subparallel veins which fork dichotomously several times before approaching the margin. They extend obliquely upward, making an angle of about 100°±.

Discussion

Formation and preservation of the fossil:

The fossil mentioned represents but a lower part of a spicate fructification, its upper part having been lost ad the specimen was broken off during field collection. The fossil was formed in a tuffaceous siltic mudstone, which is fine, stiff and compact, favourable for the formation of impressions and preservation of carbonaceous compression of the buried plant. Thus, a clear and distinct impression of the broken fructification of specimen LSJ 00845, part A, was developed. Again, due to the processes of silicification and lithification when buried, the anatomical structure in the endocarps of the nutlets was preserved. The mudstone bearing fossils is dark grey or blackish grey in colour when fresh and becomes pale yellowish on weathering. Part B of the specimen, coaly compression and impression of the fructification, are kept untouched for further investigation.

Brief review of the living *Pterocarya*

The modern genus *Pterocarya* of Juglandaceae was established by Kunth in 1842, based on the living specimens native to Transcaucasia. In China, as mentioned in "Flora Republicae Popularis Sinica, Tomus 21, 1979", eight species of the genus are reported. Among these, *P. fraxinifolia* (Lam.) Spach. grows in Transcaucasia, Iran and Turkey; *P. rhoifolia* Sieb. et Zucc. in Jiaozhouwan of Shandong, China with its distribution extending up to Japan; *P. tonkinensis* (Franch.) Dode in Southeast Yunnan, China and extending to Vietnam. The other five species— *P. stenoptera* C. DC., *P. hupehensis* Skan, *P. insignis* Rhed. & Wils., *P. macroptera* Batal. and *P. delavayi* French. are all native to China. However, *P. serrata* Schneid. has not been accepted as a new species since its traits do not extend beyond the variations of *P. stenoptera* C. DC.

Explanation of Fig. 2. *Pterocarya sinoptera* Pan Kuang, sp. nov. A. Lower part of the broken fossil fructification, (x4); B. The first (the lowest) and the second nuts in the line, (x5); C. The sixth and seventh winged nuts in the line, (x5); D. Broken moulds of the fourth and fifth nuts in the line, (x10); E. Similar porous structure of endocarp in a nut on right side of the axis, (x15).

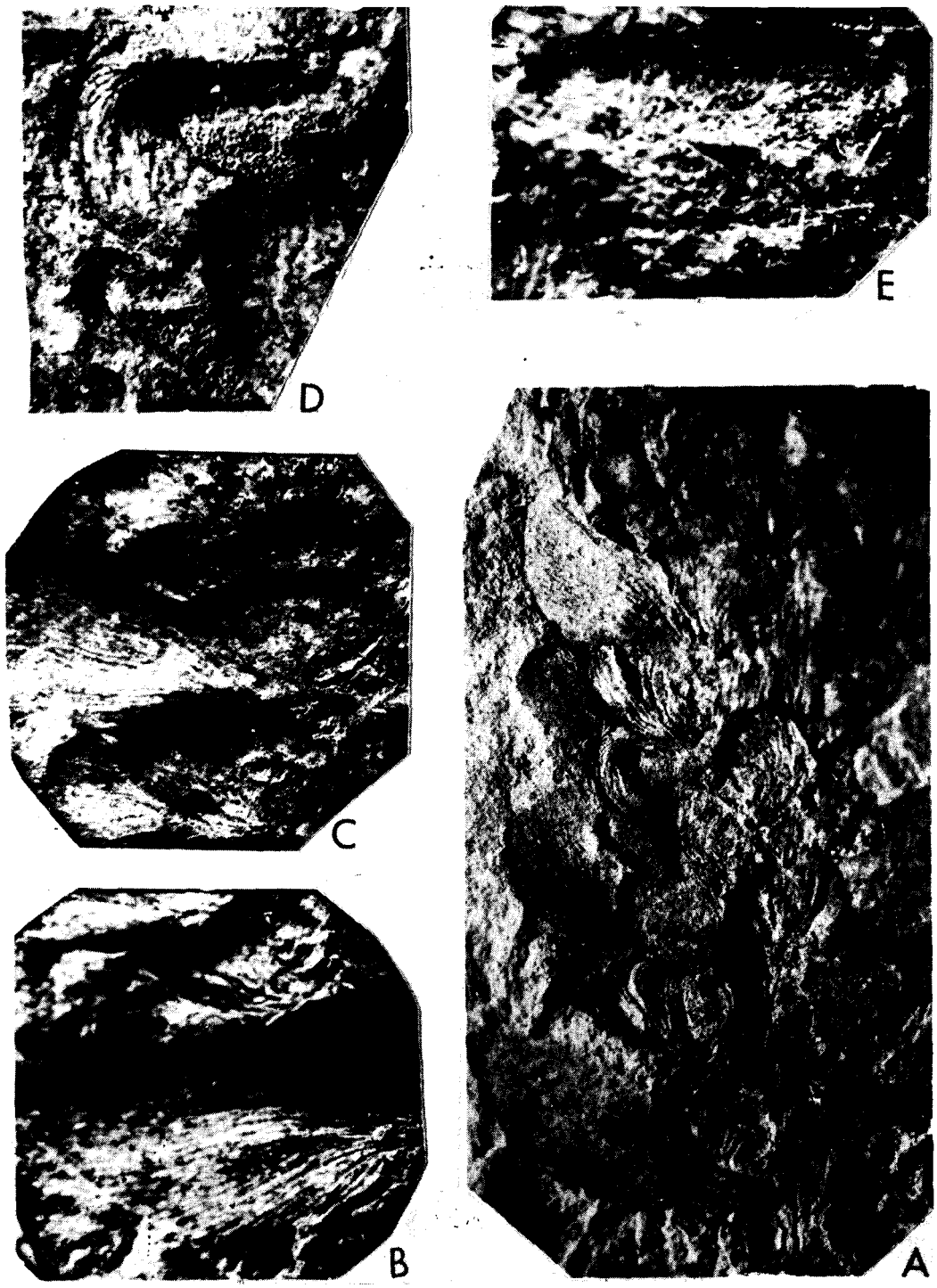

Fig. 2. *Pterocarya sinoptera* Pan Kuang, sp. nov

The eight species are classified into two sections. Section 1. Pterocarya includes *P. stenoptera, P. tonkinensis* and *P. hupehensis,* while the others are included in the Section 2. Platyptera. An important character which differentiates the two Sections is that in Section 1 the wall of endocarp of the nutlets are completely filled with loose and comparatively larger cavities formed by thin-walled cells, whereas in Section 2 such cavities are poorly developed and small in size, or even absent.

The morphological and structural features of living *Pterocarya* are well known. The specimen of the Jurassic species of *Pterocarya* acquired is only a fossil fructification and, therefore, the discussion and comparison made between the fossil and living *Pterocarya* would be restricted to the organ fructification.

Discussion and comparison of the fructifications of the Jurassic and Modern *Pterocarya*

As described above and shown in the figures, the Jurassic and modern *Pterocarya* are similar in that the many small, spheroidal and sessile winged nuts are arranged spicately on a slender axis. The only main difference is that in the fossil fructification the winged nuts are arranged more densely than in the living forms.

In living species, the fructifications are usually 20–50 cm long (13–30cm in *P. tonkinensis).* The density of arrangement of nuts could increase the burden of the axis to limit its extension, and the length of the fossil fructification may become shorter than the living forms. It is supposed to be 13–20 cm, which is about 2–3 times the length of the broken fossil.

The fructiferous axes of *P. sinoptera* sp. nov. (Jurassic fossil) and *P. stenoptera* C. DC. (living form) are both slender with thin ribs and scars of the fruits on their surface (Fig. 1:C, E; Fig. 2:A). The minor differences between them are that in the fossil form the axis is a little stout (3–4 mm across) than in the living (1–2 mm across); and the scars on the fossil axes are rounded while those on the living are elongately rhombic.

The fruits (samaras, nuts, nutlets) of both the fossil and living *Pterocarya* are similar, being small, sessile, generally spheroidal and laterally winged. The nutlets in the fossil forms are 4–6 mm in size and in the modern forms 6–8 mm in size, the difference being very little.

From the moulds and impressions of the nutlets preserved in the specimen Part A (Fig. 1: A–D; Fig. 2: A–E; Fig. 3), more structural features of the fossil nutlets can be found. As shown in the figures, there are seven moulds or impressions, entire or broken, of the nutlets arranged successively in upward sequence in a line along the left side of the axis. The first (lowest) mould (Fig. 1, D) reveals that the ribs in the exocarps are developed densely, about 4–5 in each mm, which is thicker than those in living *Pterocarya.* The second mould reveals an entire nut (Fig. 2 : A ; Fig. 3), rhomboidally spheroid in shape, with the apex mucronate and the base narrowly rounded. This form is quite like that of the nutlets of *P. tonkinensis.*

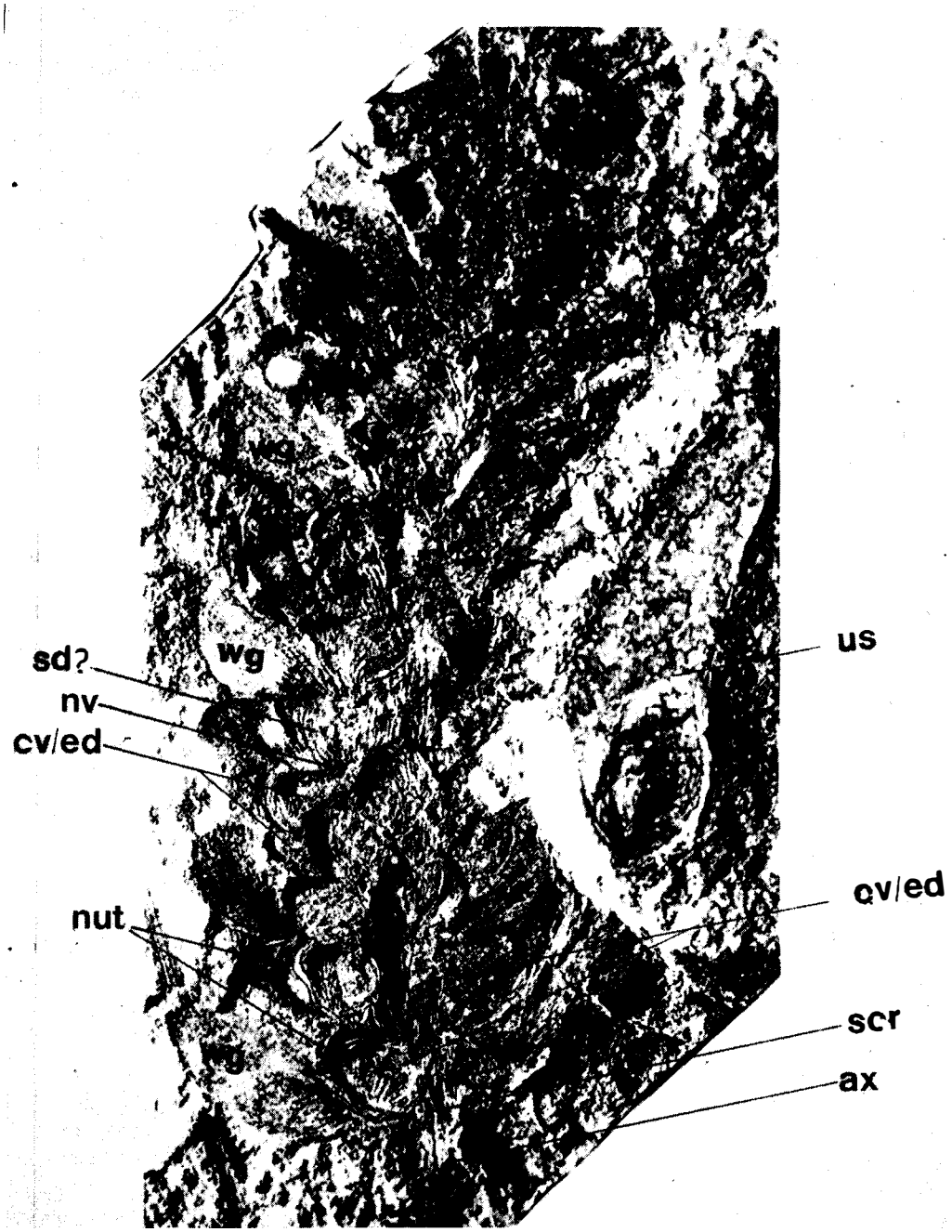

Fig.3. *Pterocarya sinoptera* Pan Kuang, sp. nov. (x3). ax: fructiferous axis; cv/ed: Cavities in endocarps; nut: nutlets; nv: navel; of nutlets; scr: scars of nutlets on the axis; sd?: seeds (?); us: undertermined samara; wg: wings of nutlets.

When illuminated under the stereoscope, two circular marks appear in pair, inside the second and sixth moulds (Fig. 2 : B, C). These are suspected to be traces of seeds(?).

In each impression of the fourth and sixth nut, a rounded mark of 0.5 mm in diam. is seen at the base, which is recognized as the navel of the fruit (Fig. 1 : C; Fig. 2 : A, C; Fig. 3). In comparison, the navel of the fruit of *P. stenoptera* is elongatedly rhomboidal.

The lateral wings of the nutlets developed in the eight living species of *Pterocarya* are of two types. Those in *P. stenoptera* and *P. tonkinensis,* of Section 1, are linear or broadly linear, 12–20 mm long and 3–6 mm wide, parallely veined, extending obliquely upward and making an acute angle between. The wings on the nuts of the living species in Section 2 have their length equal to or shorter than their width. The wings on the nuts of *P. hupehensis* are roundedly oblong, appearing to be an intermediate between the above two types.

The lateral wings on the nutlets of the Jurassic *Pterocarya* are oblong or ovate, 7–10, mm long and 4–6 mm wide (length about twice of the width), subparallely veined and extending laterally upward, making an obtuse angle, about 100°± between (Fig. 1 : A, C; Fig. 2 : A, C; Fig. 3). The wings of the fossil species resemble considerably those of the living species *P. stenoptera* and *P. tonkinensis,* both being longer, parallely veined and extending laterally upward. However, they differ in that, while one is oblong, linear and obtuse angled, the other is ovate, broadly linear and acute angled. The differences between the wings of the fossil specimen and those of the living species in Section 2, Platyptera are obvious.

In the fossil from the wing is attached at the base of the nut with a short stalk, few veins set forth there and split repeatedly to develop a series of subparallel venation, while in *P. stenoptera* the wing is attached on the side of the nut with the whole span of its broad base, many veins set forth separately and parallely from the joint, then split repeatedly to form a series of parallel venation.

Comparison of anatomical structure developed in endocarps of Jurassic and Modern *Pterocarya*

Due to lithification and silicification that took place during the geological course, the porous micro-structures in endocarps of the nutlets in the Jurassic fossil fructification were petrified and preserved beyond expectation, where the wall of the endocarp is fully filled with minute globular cavities, as seen in the endocarp of the living species *Pterocarya stenoptera.* In the first (lowest), second, third, fourth and fifth moulds, especially in the first and the last two of the nutlets lined on the left side of the fructiferous axis, the remnant pieces of endocarps with such micro-structures are seen distinctly under a stereoscope (Fig. 1 : D; Fig. 2 : A, D, E; Fig. 3). In a large piece of the endocarp on the right side of the axis, opposite to the second mould on the left side also such micro-structure can be seen well (Fig. 2 : A, E; Fig. 3). Similar porous micro-structures may be seen in all the broken pieces of the endocarps scattered in the fossil fructification. Totally, there are not less than 15 pieces.

When such micro-structures of *P. sinoptera* (fossil) and *P. stenoptera* (living) are placed together under the stereoscope for comparison, it is seen clearly that the construction of the porous micro-structures and the manner of arrangement of the minute cavities in both are closely similar. They differ only in the size of their pore; (cavity). The proportion of the size of pore (cavity) in the fossil and that the living is roughly 1.5 : 1.0 to 2:1.

The porous micro-structure of the endocarp is a trait characteristic to the genus *Pterocarya,* especially the Section 1. Pterocarya. It is conceivable that the porous cavities fully filled in endocarp will aid the samara to fly easily in the atmosphere and float lightly on water.

A comparison of the fructifications of *P. sinoptera* sp. nov. (Middle Jurassic fossil) and *P. stenoptera* (Modern, living species) is given in Table 1.

Table 1 : Comparison of the fructification of *Pterocarya sinoptera* sp. nov. (Middle Jurassic, fossil) and *Pterocarya stenoptera*

Organs \ Species		*Pterocarya sinoptera* sp. nov. (Middle Jurassic)	*Pterocarya stenoptera* C. DC. (Modern living)
Fructification	Length	Preserved 6.5 cm; may be less than 20 cm.	20–45 cm
	Diameter	2.5 cm.	3 cm ±
	Axis	3–4 mm wide, with thin ribs and circular nut-scars on surface.	1–2 mm wide, with thin ribs and elongatedly rhombic nut-scars on surface
	Nuts arranged	arranged densely	arranged loosely
Fruits	Kind of fruits	Samaras (winged nuts)	Samaras (winged nuts)
	Shape	Small, sessile, rhomboidally spheroidal.	Small, sessile, short ellipsoidal
	Size	4–6 mm.	6–8 mm
	Exocarp ribbed	ribbed densely, 5 ribs in 1 mm.	8–9 ribs in whole exocarp
	Endocarp filled	fully filled with porous cavities larger than in *P. stenoptera*	fully filled with prorus cavities smaller than in *P. sinoptera*
Wings of fruit	Mode of attachment	two lateral wings attached symmetrically on the base of nut with a short stock.	two lateral wings attached symmetrically on the side of nut with whole width of their base
	Mode of extending	extending laterally upward with an included angle 100°±.	extending obliquely upward with an included angle about 60°
	Shape and size	oblong, ovate, 7–10 mm long; 4–6 mm. wide	linear, broad linear, 12-20 mm long; 3–6 mm wide
	Venation	few veins set forth from the stock, then split repeatedly to form a sub-parallel venation. 5 veins in 1 mm near the front margin of the wing.	many veins set forth from the attaching line parallelly, then split dichotomously to form a parallel venation. 3 veins in 1mm near the front margin of the wing

SUMMARY AND CONCLUSIONS

It is clear from the above that in morphology, structural features and anatomical structures of endocarp, the Jurassic fossil fructification resembles closely the fructifications of the living species *Pterocarya stenoptera* and *P. tonkinensis* belonging to Section 1. Pterocarya. Therefore, the Jurassic fossil LSJ 00845 (A, B) is diagnosed undoubtadly by the author to be a fructification of the genus *Pterocarya* of Juglandaceae, though it was collected from the Middle Jurassic Haifanggou Formation in East Yanliao region. A new species *Pterocarya sinoptera* sp. nov. is proposed for this. Peculiarities of this new species are:

1. The fructiferous axis is comparatively stout, 3–4 mm in diam., with thin ribs and circular or rounded nut-scars on the surface.

2. The winged nuts arranged more densely on the axis than in all living species of *Pterocarya.*

3. Nuts rhomboidally spheroidal, 4–6 mm in size, exocarps ribbed densely and endocarps fully filled with globular cavities of larger size.

4. Wings of nut oblong, 7–10 mm in length and 4--6 mm in width, attached with a short stalk on the base of nut. Few veins set forth from the stalk, then split repeatedly to form a series of subparallel venation. They extend laterally upward with an included angle of 100°±.

Such peculiarities differentiate it from the allied living species *P. stenoptera* C. DC. and *P. tonkinensis* (Franch.) Dode, characterising it to be a new species.

This species is named *Pterocarya sinoptera* on account of it being found from the Middle Jurassic sediments of North China. Other organs and parts of this plant, however, are still unknown.

Stebbins (1981) wrote: "All attempts to identify any modern group of angiosperms as ancestral to the remainder of the class are futile. Even the device of adding the suffix '–like' to the name of a modern order or family is more misleading than helpful". Nevertheless, due to their close similarities, I consider the fossil species *P. sinoptera* sp. nov. may be the linear ancester of *P. stenoptera, P. tonkinensis* and *P. hupehensis* in Jurassic period.

There are not sufficient data and evidences to show the origin of *Pterocarya* of Juglandaceae. However, the majority of the living species of *Pterocarya* are native to China. The fossil of their Jurassic ancester preserved in Yanliao region of North China may be considered as a strong argument that *Pterocarya,* or even all the genera of Juglandaceae may have originated in China prior to Jurassic.

A new species of *Pterocarya* from Middle Jurassic of Yanliao region

Association of *Paliurus, Zizyphus* (of Rhamnaceae) and *Pterocarya* (of Juglandaceae) in the same fossil flora during Middle Jurassic in Yanliao region of North China suggests that Amentiferous plants are as primitive as Magnolian plants in Early Mesozoic. The possibility that they both arose in China during Late Palaeozoic Era can not be excluded.

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