International Journal of Latest Research in Science and Technology **ISSN (Online):2278-5299**
Volume 3, Issue 5: Page No.13-17,September-October 2014
https://www.mnkpublication.com/journal/ijlrst/index.php

OLIGOCENE FOSSIL WINGED FRUITS OF TRIBE *ENGELHARDIEAE* (JUGLANDACEAE) FROM THE NINGMING BASIN OF GUANGXI PROVINCE, SOUTH CHINA

[1]Yunfa Chen, [2]Steven R. Manchester, [3]Zhuqiu Song, [4]Hongshan Wang
[1]Guangxi Museum of Natural History, Nanning, China
[2]Florida Museum of Natural History, University of Florida, Gainesville, USA
[3]Guangxi Museum of Natural History, Nanning, China
[4]Florida Museum of Natural History, University of Florida, Gainesville, USA

Abstract -Two new types of fossil winged fruits of tribe Engelhardieae (Juglandaceae) are recognized in the Oligocene sediment from the Ningming Basin of Guangxi Province, south China, Palaeocarya guangxiensis sp.nov., and Alfaropsis koreanica (Oishi) Iljinskaya. The Alfaropsis koreanica fossils reported here are from the lowest latitude yet documented for the Oligocene. These fossils augment previously described engelhardioid fruit species from the same locality, Palaeocarya guangxiensis Li et Chen and Palaeocarya ningmingensis Li et Chen providing additional evidence for diversity of Juglandaceae in the Paleogene of South China, and new data for the investigation of the origin and evolution and paleobiogeographical history of the juglandaceous tribe Engelhardieae.

Keywords: *Palaeocarya*; *Alfaropsis*; *Engelhardieae*; Juglandaceae; winged fruit fossil; Oligocene; Ningming Basin; Guangxi; South China

I. INTRODUCTION

The Engelhardieae (Juglandaceae) consists of four extant genera (*Alfaroa*, *Engelhardia*, *Oreomunnea* and *Alfaropsis*), and the fossil fruit record allows recognition of four extinct genera (*Paleooreomunnea*, *Paraengelhardtia*, *Beardia*, and *Casholdia*), and one "morphogenus" (*Palaeocarya*) (Dilcher et al.,1976; Manchester, 1987; Iljinskaya, 1993; Eliott et al., 2006; Stone, 2010). These genera can be distinguished by their fruit morphology including features of the nut, style, and bract development. Among the extant genera, *Engelhardia*, *Oreomunnea*, and *Alfaropsis* have their primary bract enlarged as a trilobed dispersal wing. The genus *Alfaropsis* which was proposed by Iljinskaya (1993), and accepted as a distinct genus in subsequent phylogenetic investigations of the Juglandaceae (Manos et al., 2007; Stone, 2010), is similar to the larger genus, *Engelhardia*. Each lobe of the trilobate wing of *Engelhardia* and *Alfaropsis* fruits has pinnate venation, but those of *Alfaropsis* also have a tendency to possess some additional radiating veins from the base of the wing (Iljinskaya, 1993). Phylogenetically, *Alfaropsis* is considered sister to the *Oreomunnea* and *Alfaroa* clade, while *Engelhardia* is sister to all other *Engelhardioideae* genera (Manos et al., 2007; Stone, 2010). *Alfaropsis* was based on species that were formerly attributed to *Engelhardia*, i.e. *Engelhardia roxburghiana* and *Engelhardia fenzelii* (Iljinskaya, 1993; Manos and Stone, 2001; Manos et al., 2007). The extant species of *Engelhardia* are placed in two sections: *E. sect. Psilocarpeae* and *E. sect. Engelhardia*, including four species that now live in south China (Kuang and Lu, 1979; Lu et al., 1999).

Palaeocarya, a morphogenus founded originally by Saporta (1873), was emended by Manchester (1987) based on the uncertainty of distinguishing fossil winged fruits that display characters of both extant New World genus *Oreomunnea* and the Old World genus *Engelhardia*. Manchester (1987 p. 47) emended the generic diagnosis to include fossils with lobe venation "variable from simple pinnate to "tri-veined" (consisting of midvein and prominent ascentding lateral veins)." Two sections were proposed for the genus and they can be distinguished by the venation pattern of the lobes. *Palaeocarya* sect. *Palaeocarya* emend. Manchester has lobes with triveined lobe architecture, and *Palaeocarya* sect. *Monocosta* emend. Manchester has lobes with simple pinnate venation. Iljinskaya (1994) argued that the recognition of sect. *Monocosta* was unnecessary because such fossils usually can be placed with confidence based on fruit wing morphology and venation in the extant genera *Engelhardia* or *Alfaropsis*.

Two species of *Palaeocarya* fossils belonging to *Palaeocarya* sect. *Monocosta* were previously recognized from the Oligocene Ningming Flora of southwestern Guangxi Province (Li et al., 2003). Here we recognize a third distinct species based on additional specimens from the same site.
The Oligocene Ningming Formation yields abundant well-preserved plant and fish fossils (Li et al., 2003; Chen et al., 2004,2005; Kuang et al., 2004; Chen and Chang , 2011).

Publication History
Manuscript Received : ***12 September 2014***
Manuscript Accepted : ***29 September 2014***
Revision Received : ***28 October 2014***
Manuscript Published : ***31 October 2014***

However, only a few plant megafossil species have been formally described and published (Li et al., 2003; Chen and Zhang, 2005; Shi et al., 2010, 2011,2012; Song et al., 2014; Wang et al., 2014). Angiosperms dominate the flora, but gymnosperms and ferns are also present. The plant megafossils include Juglandaceae, Lauraceae, Leguminosae, Aceraceae, Betulaceae, Fagaceae, Hamamelidaceae, Ulmaceae, Palmae, Pinaceae, Taxodiaceae, Osmundaceae, and others.

II. MATERIALS AND METHODS

The winged fruits were found together with various fossil leaf remains from Ningming flora in 2002. The flora is from a section of the Ningming Formation (Ning et al., 1994) at the Gaoling village in Ningming County, Guangxi Province, South China (22°07.690'N, 107°02.434'E). The plant bearing strata are a set of lacustrine deposits, mainly consisting of gray, dark gray mudstone intercalated with slightly yellow shaly siltstone and fine-grained sandstone (Li et al., 2003). Because no volcanic material has been discovered at the locality, a radiometric dating was not possible. Palyno-stratigraphic correlation indicates that the Ningming Basin includes Oligocene and probably late Eocene sediment, and the Ningming Formation is Oligocene in age (Wang et al., 2003). The specimens described in this paper are stored at the Guangxi Museum of Natural History, Nanning, China.

III. DESCRIPTION OF FOSSILS

Phylum: Angiospermae
Class: Dicotyledonae
Subclass: Rosidae
Order: Fagales
Family: Juglandaceae de Candolle ex Perleb, 1818
Genus: *Palaeocarya* Saporta, 1873, emend. Manchester, 1987

Palaeocarya gaolingensis Yun-Fa Chen, sp. nov.
Holotype: NHMG011623, designated here (Fig.1)
Paratype: NHMG011624 (Fig.2)
Repository: Guangxi Museum of Natural History, China
Type locality: Ningming County, Guangxi Province, China (22°07.690'N, 107°02.434'E)
Stratigraphic horizon: Ningming Formation, Oligocene
Etymology: Species name referring to the occurrence of the fossils at Gaoling village

Diagnosis: Trilobate winged fruits; median lobe obovate, lobe apex rounded to retuse; lateral lobe oblong; midvein very strong and straight, terminating at the lobe apex with a mucronate thickening; one pair of first secondary veins of each lobe diverging from the extreme base of the midvein at very narrow angles; strong and prominent secondary veins, relatively few; nutlet small; pedicel long.

Description: Fruit wing trilobed; central lobe obovate, 23-34 mm long and 3-10 mm wide; lateral lobes oblong, 14-20 mm long and 3-6 mm wide, diverging from the central lobe at 35°-50°; margin of lobes entire, apex rounded to slightly retuse and mucronate. Venation of lobes pinnate; midvein very strong, straight, extending to the lobe apex and forming a mucro. Secondary veins strong, 4-6 pairs per lobe; first pair of secondary veins of each lobe diverging from the extreme base of the midvein at very acute angles (10-15°), ascending along the margin about 1/3 to 2/3 of the lobe length before joining coalesced adjacent secondary loops; other secondary veins brochidodromous, diverging from the midvein at angles of 35-70°, the angles decreasing from the apex to the base. Tertiary veins prominent and irregular in course; quaternary veins fine, anastomosing and forming meshes. Prophyllum not observed, nutlet not well preserved; detachment scar of one nutlet in one specimen small, about 2 mm in diameter; pedicel relatively long (7 mm).

Comparison and discussion: Fruits of extant *Oreomunnea* from the New World tropics, and of *Engelhardia* and *Alfaropsis*, from the Old World tropics, are all characterized by relatively large trilobed bracts that aid in dispersal of the nut. The nuts of *Engelhardia* and *Alfaropsis* species are partitioned into 2 or 4 compartments at the base, while those of *Oreomunnea* species have 8 basal compartments (Stone, 1972, 2010; Xie et al., 2010). However, the nuts are not preserved in the specimens at hand, so we are uncertain of the number of partitions. Lacking the information to place these fruits securely in an extant genus, we consider it best to assign the species to *Palaeocarya*.

The species is distinguishable from *Oreomunnea* whose winged fruits have three prominent primary veins in each lobe, and differs from extant *Engelhardia* species that have a strictly pinnate venation pattern in each of the three lobes.

The fossil is similar to the extant species *Alfaropsis roxburghiana* (formerly *Engelhardia roxburghiana*) in having weak ascending veins radiating from the base of the lobes, giving a venation pattern somewhat intermediate between *Engelhardia* and *Oreomunnea*. However, the fossil species is distinct because its midvein doesn't reach to the lobe apex but divides to form marginal looping series of two orders (Tanai and Uemura, 1983; Guo and Zhang, 2002). As for the small angle between midvein and first secondary vein in the lobe, this species is comparable to *Alfaropsis koreanica*, but this species is characterized by its very strong midvein, strong and prominent secondary veins, obovate median lobe, rounded to retuse lobe apex. *P.guangxiensis* and *P. ningmingensis* previously reported from the same locality have typically pinnate venation in the lobes (Li et al., 2003), which differ from the current specimens. The specimens are distinguished from the previously reported species (see Table 1). A new species under *Palaeocarya* is therefore proposed: *Palaeocarya gaolingensis*

Alfaropsis koreanica (Oishi) Iljinskaya 1993 (Fig.3)
Description: One specimen represented by part (NHMG 011625) and counterpart (NHMG011626) (Fig.3). Fruit wing trilobed; central lobe longer than lateral ones, oblanceolate, 34 mm long and 4-6 mm wide; lateral lobes oblanceolate to narrowly elliptic, 20 mm long and 5-7 mm wide, diverging from the central lobe at 50°-60°; margin of lobes entire, apex obtuse. Venation of lobes pinnate; midvein strong, nearly straight, ending at the lobe apex with a mucronate thickening. Secondary veins fine yet prominent, 9 pairs in the central lobe; the first pair of secondary veins of each lobe diverging from the extreme base of the midvein at very acute angles (about 15°), ascending along the margin about 1/3 to 1/2 of the lobe length before joining coalesced adjacent secondary loops; other secondary veins brochidodromous, diverging from the midvein at 35-55°, angles gradually decreasing from the apex to the base. Tertiary veins irregular in course; quaternary veins anastomosing and forming meshes. Prophyllum and nutlet not present; detachment scar of

nutletabout 1 mm in diameter. Pedicel present, about 10 mm long and 1 mm wide.

Discussion: In gross fruit wing morphology, the specimens presented here are somewhat similar to the fruits of *Palaeocarya guangxiensis* Li et Chen from the same horizon. They differ in that the first pair of secondary veins of the middle lobe diverges from the extreme base of the midvein at distinct acute angles (about 15°), appearing to be similarly tri-veined, however, the upper 2/3s of the middle lobe possesses pinnate venation. The fruit wing lobes of *Palaeocarya guangxiensis* Li et Chen have pinnate venation, and thus may conform to the extant genus *Engelhardia*. The current specimens resemble the fossils *Engelhardtia koreanica* Oishi (later transferred to *Alfaropsis koreanica* Iljinskaya) recorded in East Asia (Oishi,1936; Akhmetyev and Bratzeva, 1973; Iljinskaya 1994). That species was also assigned by Manchester (1987) to the genus *Palaeocarya*. Following Iljinskaya's arguments, we adopt the binomial *Alfaropsis koreanica.* The long stout petiole is a distinctive feature shared by both *Alfaropsis koreanica*, and *Palaeocarya gaolingensis.* Although the authors (Li and Chen, 2003) designated several specimens collected from the same locality as syntypes for the species *Palaeocarya guangxiensis* and *P. ningminensis*, the International Code of Botanical nomenclature requires a single specimen (holotype) as the type for a species. In order to validate these species, lectotype designations are now required. *For Palaeocarya guangxiensis*, we hereby designate the lectotype as NHMG006014 (Li and Chen, 2003, pl.1, fig.8; text fig. 1) and for *Palaeocarya ningmingensis*, the lectotype is here designated as NHMG 005998 (Li and Chen, 2003, pl.1, fig.6; text fig.7).

In summary, we now recognize four species of engelhardioid fruits from the Ningming flora, *i.e. P. guangxiensis* and *P. ningmingensis* (Both very similar to extant *Engelhardia* in wing venation), and, *A.koreanica* and *P.gaolingensis* (both similar to extant *Alfaropsis*) (see Table 1). They are distinguished by venation patterns, lobe shape, nutlet and pedicel length.

IV. DISCUSSION

Engelhardioid fruit fossils have been found well outside their modern geographic ranges in strata from the Eocene to the Pliocene in Europe (Jähnichen et al., 1997; Fischer and Butzmann, 2006; Bertini and Martinetto, 2008) and from the Eocene to Miocene in North America (Dilcher et al., 1976; Manchester, 1987, 1994), as well as Asia(Xie et al., 2010).

In Asia, engelhardioid fossils were reported from Korea, Far East Russia, Japan and China. The species is *Alfaropsis koreanica* (=formerly *Engelhardtia koreanica*) from the late Oligocene Kogeonweon Formation in Kogeonweon in North Korea (Oishi,1936; Huzioka,1972; Tanai and Uemura, 1983), from late Oligocene Sikhote-Alin flora in Far East Russia (Akhmetyev and Bratzeva, 1973), and from middle-late Oligocene Wakamatsuzawa Formation in Kitami and Poronai Formation in Yubari in Japan (Tanai and Uemura, 1983; Tanai,1992). In China, two specimens of an undetermined *Palaeocarya* species were recovered from the Eocene Changchang Formation in Qiongshan County of Hainan Province (Jin, 2009); three specimens of *P. koreanica* from Oligocene Sanhe Formation in Longjing County of Jilin Province (Guo et al., 2002); numerous specimens of *Palaeocarya* from Oligocene Ningming Formation in Ningming County of Guangxi Province (Li et al., 2003); six specimens of *Palaeocarya* from upper Pliocene Mangbang Formation in Tenchong County of Yunnan Province (Xie et al., 2010).

Besides these two species of tribe *Engelhardieae* (Juglandaceae) presented in this paper, we have previously reported two *Palaeocarya* sect. *Monocosta* fossil species: *Palaeocarya guangxiensis* Li Hao-Min et Chen Yun-Fa and *Palaeocarya ningmingensis* Li Hao-Min et Chen Yun-Fa on the basis of numerous fossil specimens from the same locality as our new species (Li et al., 2003). Considering the diversity of the *Engelhardieae* species and abundance of fossils, particularly *Palaeocarya guangxiensis* (Li et al., 2003), we propose that Ningming was a center of evolution and differentiation of *Engelhardieae* in late Eocene/Oligocene in South China. Today this region, and Southeast Asia, is the distribution center of the related modern genera *Engelhardia* and *Alfaropsis*.

In China, *Alfaropsis koreanica* fossils occur in two other localities: the Oligocene sediments in Jilin Province in northeastern China (41°29′30″N, 129° 43′20″E)(Guo and Zhang, 2002) and the Pliocene strata in Yunnan Province in south China (24° 41′ 13″N, 98° 37′ 59″E)(Xie et al., 2010). The *Alfaropsis koreanica* fossils reported in this paper are from the lowest latitude, indicating that the species had a wide latitudinal range in the Oligocene, and that the genus survived in the southern end of its range despite the effects of Paleogene to Neogene climate change (Zachos et al., 1994, 1996, 2001; Mosbrugger et al., 2005).

ACKNOWLEDGEMENTS

We thank colleagues Chen Gengjiao, Kuang Guodun and Huang Chaolin for assistance in the field work. This research was supported by the National Natural Science Foundation of China (No.41162002) and China Scholarship Council Project.

REFERENCES

[1] Akhmetyev M A, Bratzeva G M, "Fossil Remains of the Genus *Engelhardtia* from Cenozoic Deposits of Sikhote-Alin and Southern Primorye", Review of Palaeobotany and Palynology 16:123-132, 1973.

[2] Bertini,A., Martinetto,E., "Messinian to Zanclean vegetation and climate of Northern and Central Italy", Bollettino della società Paleontologica Italiana 47, 105-121, 2008.

[3] Chen, G. J., Chang, M. M.," A new early cyprinin from Oligocene of South China", Science China, Earth Sciences 54(4): 481-492, 2011.

[4] Chen, G. J., Chen,Y. F., Huang, G. D., Zhu, Q. P., "Biostratigraphy of Tertiary fossil fishes from Ningming Basin, Guangxi", Vertebrata Palasiatica 42(1): 81-85, 2004 (in with English abstract).

[5] Chen,G. J., Fang, F., Chang,M.M., "A new cyprinid closely related to cultrins+xenocyprinins from the Mid-Tertiary of South China", Journal of Vertebrate Paleontology 25(3): 492-501, 2005.

[6] Chen, Y. F., Zhang, D. X., "*Bauhinia larsenii*, a fossil legume from Guangxi, China", Botanical Journal of the Linnean Society 147: 437-440, 2005.

[7] Dilcher,D.L., Potter,F.W., Crepet,W.L., "Investigations of angiosperms from the Eocene of North America: juglandaceous winged fruits", American Journal of Botany 63, 532-544, 1976.

[8] Elliott, L.L., Mindell, R.A. Stockey, R.A. "*Beardia vancouverensis* gen. et sp. nov. (Juglandaceae): permineralized fruits from the Eocene of British Columbia", American Journal of Botany 93(4): 557–565. 2006.

[9] Fischer,T.C., Butzmann,R., "The Pliocene macro- and microflora of lacustrine sediments from Meleto (Valdarno, N. Italy) and its ecological, palaeobiogeographical and climatic interpretation", Cainozoic Research 5, 71-88, 2006.

[10] Guo, S. X., Zhang, G. F., "Oligocene Sanhe Flora in Longjing County of Jilin, Northeast China", Acta Palaeontologica Sinica 41(2): 193-210, 2002.

[11] Huzioka, K., "The Tertiary floras of Korea", Journal of the Mining College, Akita University, Series A 5: 1-83, 1972.

[12] Iljinskaya, I. A., "*Alfaropsis*, a new genus of the Juglandaceae", *Bot. Zhurn. (Moscow & Leningrad)*78:79–83, 1993 (in Russian with English summary, , translated by B. M. Johnson, Duke University).

[13] Iljinskaya, I.A., "*Alfaropsis korenica*" in Budantsev,L.,ed. Fossil Flowering Plants of Russia and Adjacent States (Vol.3), 41-42, 1994 (in Russian).

[14] Jähnichen, H., Mai, D. H., Walther, H., "Blätter und Fruchte von *Engelhardia* Lesch. Ex BL. (Juglandaceae) aus dem europäishen Tertiär", Feddes Reperotorium 88: 323-363, 1977.

[15] Jin,J.H., "Two Eocene Fossil Fruits From the Changchang Basin of Hainan Island China", Review of Palaeobotany and Palynology 153,150-152, 2009.

[16] Kuang, G. D., Chen, G. J., Chen Y. F., Huang, Z. T., "New information on the Tertiary biostratigraphy of the Ningming Basin, Guangxi", Journal of Stratigraphy 28(4): 362-367, 2004 (in Chinese with English abstract).

[17] Kuang,K.Z., Lu,A.M., Juglandaceae. Delectis florae reipublicae popularis sinicae agendae academiae sinicae edita, Flora reipublicae popularis sinicae, tomus 21. Science Press, Beijing, pp.11-18, 1979(in Chinese).

[18] Li,H.M., Chen,Y.F.,Chen,G.J., Kuang,G.D., Huang,Z.T., "Tertiary Fossil Winged Fruits of *Palaeocarya* from Ningming of Guangxi, S. China", Acta Palaeontologica Sinica 42（4）：537-547, 2003 (in Chinese with English abstract).

[19] Lu,A.M., Stone,D.E., Grauke,L.J., Juglandaceae. Flora of China 4, 277-285, 1999.

[20] Manchester S R, The fossil history of the Juglandaceae. Monographs in Systematic Botany from the Missouri Botanical Garden, 21: 1 – 137, 1987.

[21] Manchester, S.R., Collinson,M.E., Goth,K., "Fruits of the Juglandaceae from the Eocene of Messel, Germany, and implications for early Tertiary phytogeographic exchange between Europe and west North America", International Journal of Plant Sciences 155, 388-394, 1994.

[22] Manos, P. S., Soltis,P. S., Soltis,D. E., Manchester,S. R., Oh,S-H., Bell, C. D., Dilcher, D. L. ,Stone, D. E., "Phylogeny of extant and fossil Juglandaceae inferred from the integration of molecular and morphological data sets", Systematic Biology 56(3):412–430, 2007.

[23] Manos, P. S., Stone, D. E., " Evolution, phylogeny, and systematics of the Juglandaceae", Annals of the Missouri Botanical Garden 88:231–269, 2001.

[24] Mosbrugger,V.,Utescher,T.,Dilcher,D.L., "Cenozoic Continental Climatic Evolution of Central Europe", PNAS 102(42):14964-14969, 2005.

[25] Ning, Z. S., Zhou,T. M., Hu, Y. K., Liang , Z. H., Tertiary in Petroliferous Regions of China. Petroleum Industry Press, Beijing, pp. 13-19, 1994 (in Chinese).

[26] Oishi,S., "A note on the genus *Engelhardia*, and its occurrence in Palaeogene of Korea", The Journal of the Geological Society of Japan, 43 (508):56-59, 1936.

[27] Saporta, G.,Études sur la Végétation du sud-est de la France à L'époque Tertiaire. Supplement I: Révision de Flore des Gypses d'Aix. Annales des Sciences Naturelles 5e série 18: 23-146, 1873.

[28] Shi, G. L., Zhou, Z. Y., Xie, Z. M., "A new Cephalotaxus and associated epiphyllous fungi from the Oligocene of Guangxi, South China", Review of Palaeobotany and Palynology 161: 179-195, 2010.

[29] Shi,G.L., Zhou, Z.Y., Xie, Z.M., "Cupressus foliage shoots and associated seed cones from the Oligocene Ningming Formation of Guanggxi, South China", Review of Palaeobotany and Palynology 166: 325-334, 2011.

[30] Shi,G.L., Zhou, Z.Y., Xie, Z.M., "A new Oligocene *Calocedrus* from South China and its implications for transpacific floristic exchanges", American Journal of Botany 99: 108-120, 2012.

[31] Song, Z.Q., Shi,G.L. Chen, Y.F., Wang,Q., "Winged fruits of *Ailanthus* (Simaroubaceae) from the Oligocene Ningming Formation of Guangxi, and their taxonomic and biogeographic implications", Acta Palaeontologica Sinica 53 (2): 199-200.

[32] Stone,D.E., New world Juglandaceae. A new perspective of the tropical members with winged fruits. Annals of the Missouri Botanical Garden 59, 297-322, 1972.

[33] Stone, D.E., "Review of New World Alfaroa and Old World Alfaropsis (Juglandaceae)", Novon: A Journal for Botanical Nomenclature 20(2): 215-224, 2010.

[34] Tanai, T., "Juglandaceae from the Paleogene of Hokkaido, Japan", Bulletin of the National Science Museum, Tokyo, Series C 18(1): 13-41, 1992.

[35] Tanai T, Uemura K, "*Engelhardtia* fruits from the Tertiary of Japan", Journal of Faculty of Science., Hokkaido University, Series. IV, 20(2-3):249-260, 1983.

[36] Wang, Q., Song,Z.Q., Chen,Y.F., Shen,S., Li,Z.Y., "Leaves and fruits of *Bauhinia* (Leguminosae, Caesalpinioideae, Cercideae) from the Oligocene Ningming Formation of Guangxi, South China and their biogeograghic implications", BMC Evolutionary Biology 14:88, 2014.

[37] Wang,W.M., Chen,G.J. , Chen,Y.F., Kuang,G.D., "Tertiary Palynostratigraphy of the Ningming Basin, Guangxi", Journal of Stratigraphy 27(4): 324-327, 2003(in Chinese with English abstract).

[38] Xie,S.P.,Sun,B.N,Dilcher,D.L.,Yan,D.F.,Wu,J.Y.,Lin,Z.C., "Numerical taxonomy of *Palaeocarya* (Juglandaceae) from the Mangbang Formation of West Yunnan, China", Review of Palaeobotany and Palynology 162(2): 193-202, 2010.

[39] Xie,S.P.,Sun,B.N.,Yan,D.F.,Cong,P.Y.,Xiao,L.,Wei,L.J., "Stomata,carbon Isotopic composition of the plants From the Neogene in West Yunnan and Paleoenvioronmental Analysis", Acta Sedmentologica Sinica 24(6):883-888, 2006 (in Chinese with English abstract).

[40] Zachos,J.C., Stott,L.D., Lohmam,K.C., "Evolution of Early Cenozoic marine temperatures", Paleoceanography 9, 353-387, 1994.

[41] Zachos,J.C.,Quinn,T.M.,Salamy,K.A., "High-Resolution(10^4Years) Deep-sea Foraminiferal Stable Isotope Records of the Eocene-Oligocene Climate Transition", Paleocenography 11(3):251-266, 1996.

[42] Zachos,J.,Pagani,M.,Sloan,L.,Thoma,E.,Billups,K., "Trends, rhythms and aberrations in global climate 65Ma to Present", Science 292(5517):686-693, 2001

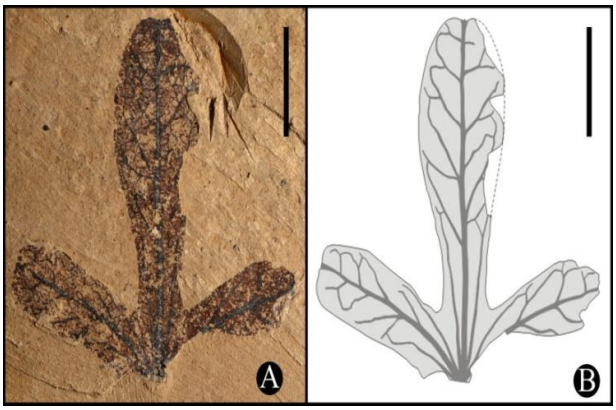

Fig.1. Holotype specimen of *Palaeocarya gaolingensis* Yun-Fa Chen, sp. nov. Specimen (NHMG011623)(A) and its sketch(B) showing lobes and major venation, currently preserved in the Guangxi Museum of Natural History, China. Scale bar = 1 cm.

Fig.2. Paratype specimen of *Palaeocarya gaolingensis* Yun-Fa Chen, sp. nov. Specimen (NHMG 011624), currently preserved in the Guangxi Museum of Natural History, China. Scale bar = 1 cm.

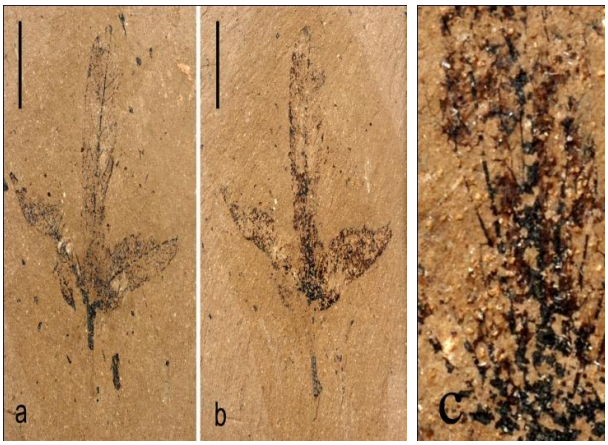

Fig.3. *Alfaropsis koreanica* (Oishi) Iljinskaya 1993. Winged fossil fruit part (a) and counterpart (b) of the specimen (NHMG011625 and NHMG011626, currently preserved in the Guangxi Museum of Natural History, China. Scale bar = 1 cm). Enlargement (c) showing first pair of secondary vein in the median lobe of the specimen counterpart (b).

Table 1. Comparisons of lobe venation and pedicel between selected species

Species	**major lobe venation**	**midvein strength**	**midvein reaching apex**	**radiating veins from base of bract**	**pedicel length (mm)**	**other observations**
P.gaolingensis sp. nov.	typically combining pinnate and triveined	very strong	yes	yes	7	secondary veins strong and few
P. guangxiensis Li et Chen	pinnate	strong	yes	no	2.5-6	secondary veins fine, brochidodromous
P. ningmingensis Li et Chen	pinnate	moderate	yes	no	unknown	secondary veins fine, eucampto-dromous in the lower part, brochidodromous in the middle and upper parts of the lobe
A. koreanica (Oishi) Iljinskaya	pinnate	strong	yes	yes	up to 10	Secondary veins fine, a pair of thin basal veins follow a very acute angle to the primary vein
A. roxburghiana	pinnate	strong	no	yes	2-8	Secondary veins fine
Oreomunnea extant species	triveined	up to very strong	yes or no	yes	2-4	
Engelhardia extant species	pinnate	up to strong	yes or no	no	0-2	