Review of Palaeobotany and Palynology 193 (2013) 119–127

Contents lists available at SciVerse ScienceDirect

Review of Palaeobotany and Palynology

journal homepage: www.elsevier.com/locate/revpalbo

Research paper

Fruits of *Schima* (Theaceae) and seeds of *Toddalia* (Rutaceae) from the Miocene of Yunnan Province, China

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ARTICLE INFO

Article history:
Received 1 March 2012
Received in revised form 11 January 2013
Accepted 29 January 2013
Available online 19 February 2013

Keywords:
Schima
Toddalia
phytogeography
Miocene
Yunnan
China

ABSTRACT

Fossil fruits of *Schima* (Theaceae) and seeds of *Toddalia* (Rutaceae) have been described as *Schima nanlinensis* sp. nov. and *Toddalia nanlinensis* sp. nov. respectively, from the Miocene of Nanlin Formation in Longchuan Basin, Dehong Autonomous Prefecture, Yunnan Province, China. The former are 5-loculed capsules with loculicidal dehiscence and remains of calyx at the base, as well as reniform flat seeds, while the latter are boat-shaped seeds with tegmen that is composed of thin-walled cells with fine criss-crossed spiral lignifications. The genus *Schima* Reinwardt ex Blume is known from the Palaeogene and Neogene of Germany and Austria, but today it is confined to South, East and Southeast Asia. *Schima nanlinensis* sp. nov. represents the first fossil record of the genus in Asia. The genus *Toddalia*, known to have existed in Europe from Eocene to Pliocene, is now widely distributed from Africa to Asia. *Toddalia nanlinensis* sp. nov. is the first fossil record of the genus in Asia and suggests that the genus probably extended the geographic distribution from Europe to Asia at least in the Miocene.

1. Introduction

Schima Reinwardt ex Blume is a genus of evergreen trees belonging to the tea family, Theaceae. The genus was once reported from the Palaeogene and Neogene of Germany and Austria (Mai, 1971; Kovar-Eder and Hably, 2006), but now it is confined to South, East and Southeast Asia, from the eastern Himalaya of Nepal and northeastern India to Bhutan, Cambodia, China, Indonesia, Japan (Ryukyu Islands), Laos, Malaysia, Myanmar, Thailand and Vietnam (Keng, 1994; Min and Bartholomew, 2007). *Toddalia* Jussieu is a monotypic genus in the citrus family (Rutaceae), containing the single species *Toddalia asiatica* (Linnaeus) Lamarck. The genus has abundant seed fossils recorded from the Eocene to early Pliocene of Europe (Gregor, 1979). Now the genus is widely distributed from West Africa, Madagascar, Mascarene Islands to South, East and Southeast Asia (Zhang et al., 2008). Amazingly, there is no fossil record of the two genera in Asia, although they are now present in South, East and Southeast Asia.

This work recently recognized anatomically preserved fruits of *Schima nanlinensis* sp. nov. and seeds of *Toddalia nanlinensis* sp. nov. from the Miocene of Nanlin Formation in Longchuan Basin, Yunnan Province, China. The fruits and seeds respectively represent the first fossil record of *Schima* and *Toddalia* in Asia, and thus provide important evidence for the phytogeographical history of the two genera. Besides, they are the newly discovered taxa to be described for the formation, on which a lot of work has been done previously.

The study of plant megafossils from the Nanlin Formation was initiated by Jiang and Li (1984), who identified 17 taxa including 1 gymnosperm: *Calocedrus lantenoisii* Laurent and 16 angiosperm: *Acer* sp., *Alnus* sp., *Betula* sp., *Celtis bangeana* Blume, *Dryophyllum* cf. *yunnanense* Colani, *Dryophyllum* sp., *Fagus* sp., *Fraxinus* sp., *Hamamelis* sp., *Magnolia* sp., *Quercus* cf. *liaotungensis* Koidzumi, *Rhus miosue-cedanea* Hu et Chaney, *Smilax* sp., *Tilia* sp., *Ulmus* sp. and *Zelkova* sp. Later, Zhao et al. (2004) studied the fruits and seeds belonging to 11 angiospermous taxa, viz. *Corylopsis uralensis* Dorofeev, *Ficus* sp., *Hypericum* sp., *Lithocarpus* sp., Lauraceae, *Magnolia* sp., *Myrica kirchheimeri* Friis, *Nyssa* sp., *Sabia europaea* Czeczott et Skirgiello, *Symplocos* cf. *germanica* Mai, and *Zanthoxylum tertiaria* (Heer) Gregor et Hantke. Lin et al. (2000) carried out palynological analysis on the same formation. The spores and pollens recovered belong to ferns, conifers and broad-leaved angiosperms. On the basis of both micro- and macrofossil assemblages, Lin et al. (2000) and Zhao et al. (2004) suggested that an evergreen broad-leaved forest existed under subtropical climate around Longchuan Basin in the Miocene. The new findings in this article further confirm previous assumptions on vegetation and climate of the Nanlin Formation.

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http://dx.doi.org/10.1016/j.revpalbo.2013.01.008

2. Materials and methods

Longchuan Basin is located in Longchuan and Ruili Counties, western Yunnan province, China. It has well developed Neogene strata which consist of the Nanlin Formation and the Mangbang Formation. On the basis of lithology, the Nanlin Formation is subdivided into the upper, middle and lower members. The lower member consists of gray to light gray conglomerate with intercalated sandstone and siltstone; the middle one is a coal-bearing stratum, containing mudstone, carbonaceous mudstone and coal, as well as intercalated sandstone; the upper member contains mainly gray green mudstone with intercalated sandstone (Lin et al., 2000). Of these, the coal bearing middle member is rich in plant fossils.

Based on lithostratigraphy and biostratigraphy, the age of the Nanlin Formation is considered as early to middle Miocene (Jiang and Li, 1984; Bureau of Geology and Mineral Resources of Yunnan Province, 1990; Ge and Li, 1999; Lin et al., 2000).

The fossil fruits and seeds studied here were collected from Xiandongzhai coal mine (97°54′E, 24°29′N), belonging to Nanlin Formation, at the Longchuan County, Yunnan Province, China (Fig. 1). They are preserved in three-dimensions. The specimens were cleaned in 10% dilute hydrochloric acid, followed with 48% hydrofluoric acid and thoroughly washed in water and dried in air. They were observed and photographed under a Nikon SMZ1000 stereomicroscope and a FEI Quanta-200 ESEM (Environmental Scanning Electronic Microscope). All specimens are deposited in the National Museum of Plant History of China, Institute of Botany, Chinese Academy of Sciences, Beijing, China. The terminology used to describe the seeds of *Toddalia* follows Corner (1976) and Gregor (1979).

3. Results

Order: Ericales
Family: Theaceae
Genus: *Schima* Reinwardt ex Blume
General description of fruits and seeds of *Schima*: Sepals are 5 (rarely 6), imbricate, persistent, slightly connate at base; capsule is globose or depressed globose; pericarp is woody, loculicidally splitting for 1/2 length into 5 (rarely 6) valves; columella is persistent, stout, extending for 2/3 or more of locule length, apically 5 (rarely 6) angled; seeds are small, reniform, flat, with a marginal membranous wing (Bloembergen, 1952; Keng, 1994; Min and Bartholomew, 2007).
Species: *Schima nanlinensis* Li et al. sp. nov.
Specific diagnosis: Fossil fruits with general characters of extant *Schima*, but also with the following specific features. Capsule depressed globose, 6–9 mm long, 8–11 mm wide; sepals about 2 mm in diameter; Seeds 6.5–7.5 mm long, 4.0–5.0 mm wide.
Holotype: IBCAS2007M015
Paratype: IBCAS2007M013, 014, 016a, 016b, 016c.
Type stratum: Nanlin Formation
Geological age: early to middle Miocene
Type locality: Xiandongzhai coal mine, Longchuan County, Yunnan Province, China
Repository: National Museum of Plant History, Institute of Botany, Chinese Academy of Sciences, Beijing, China.

Description: Totally 6 complete fruits, 10 isolated vales or fragments and 5 in situ seeds were available for the study. Capsule is depressed globose, 6–9 mm long and 8–11 mm wide. Fruit width/length ratio is 1.11–1.37. Pericarp is not fully dehiscent to release seeds, but only slightly dehiscent into five valves (Plate I, 1–3). Sepals are persistent, imbricate, surround the capsule, about 2 mm in diameter (Plate I, 3). Gynecium is superior indicated by the remains of calyx. Columella is persistent, stout and extending for two-thirds or more of locule length. Columella is apically five-angled, with an enlarged face inside each of the five locules (Plate I, 4–5). Seeds are still kept in locules and attached to the pericarp due to compression during preservation. They are reniform, flat, 6.5–7.5 mm long, 4.0–5.0 mm wide (Plate I, 4–6), sub-campylotropous orientated. Seed width/length ratio is 0.62–0.71. Seed has no clear membranous wing in the specimens, but shows curled margin (Plate I, 5–6). Pericarp is sclerenchymatous with tangentially elongate cells in cross-section (Plate I, 7–9).

Comparison: There are several families including Bombacaceae, Malvaceae, Pentaphylaceae, Sterculiaceae, Theaceae, and Tiliaceae

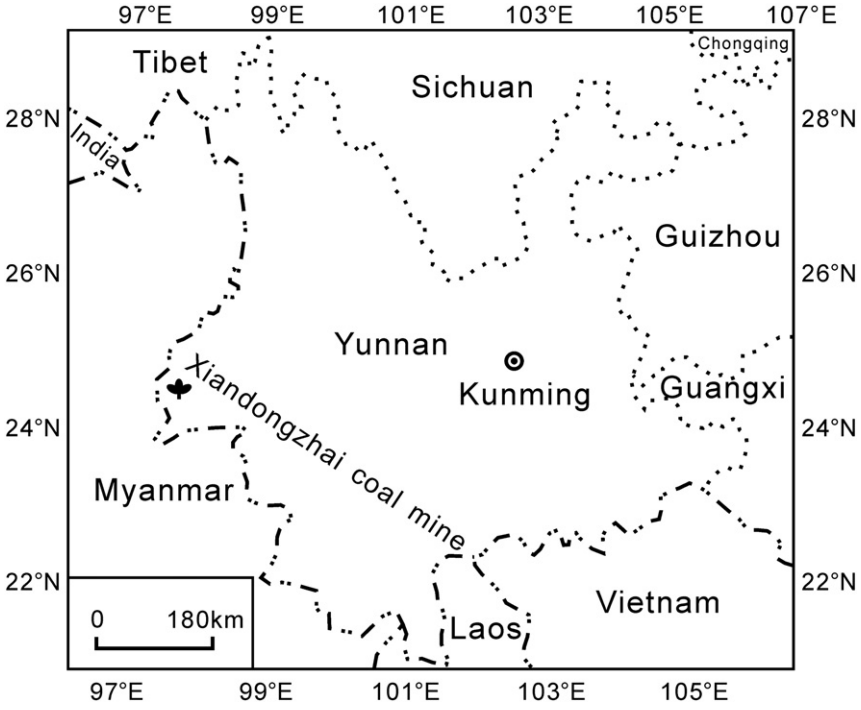

Fig. 1. Map of Yunnan Province, China shows location of Xiandongzhai coal mine (97°54′E, 24°29′N).