Occurrence of Late Miocene flora from north-east China

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A flora containing both plant microfossils and megafossils has been reported from four placer gold wells in Huanan County, Heilongjiang Province of north-east China. Most of the pollen and megafossil plants are in common. Families Fagaceae, Betulaceae and Pinaceae are abundant in this fossil flora which probably imply a mixed conifer and deciduous broad-leaved forest of warm temperate climate. On the basis of associated vertebrate fossils and correlation with equivalent floras a Late Miocene age has been assigned.

Key-words—Plant megafossils, Palynology, Late Miocene (China).

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सारांश

उत्तर-पूर्व चीन से अनंतिम मध्यनूतन वनस्पतिजात की प्राप्ति

लियु गेंगवु, ली हाओमिन एवं लेंग किन

उत्तर-पूर्व चीन के हीलोंगजियाँग प्रान्त में हुआनन काउन्टी के चार कुओं से सूक्ष्म-एवं गुरुपादपाश्मों से युक्त समुच्चय प्राप्त हुई है। उपलब्ध परागकण एवं गुरुपादपाश्मों में से अधिकतर सामान्यतया मिलने वाले अवशेष हैं। फैगेसी, बिटुलेसी, पाइनेसी नामक कुलों के अवशेष प्रचुरता में मिलते हैं जो सम्भवतया गर्म शीतोष्ण जलवायु वाले मिश्रित कोनिफर एवं पर्णपाती चौड़ी पत्ती वाले वनों की विद्यमानता इंगित करते हैं। सहयुक्त रीढ़धारी जीवाश्मों एवं समतुल्य वनस्पतिजातों के आधार पर इन निक्षेपों की अनंतिम मध्यनूतन आयु प्रस्तावित की गई है।

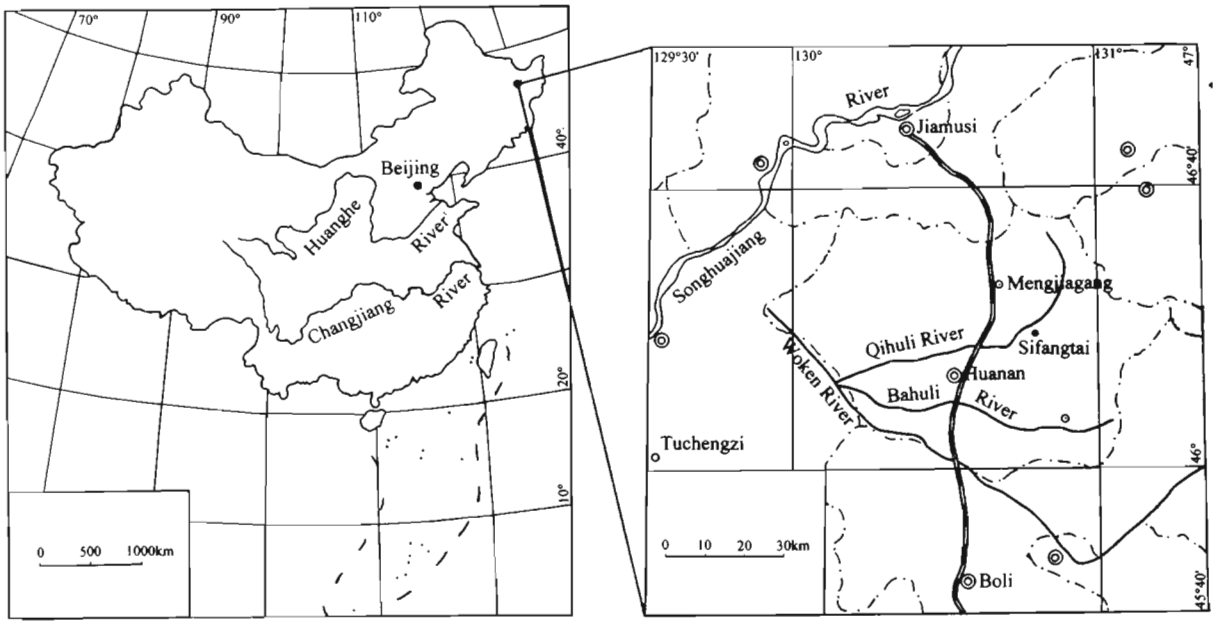
IN the vast area of northern and northeastern China the Late Miocene and Early Pliocene sediments are mostly red clay, coarse sand or gravels with vertebrate fossils. Few fossil leaves have been reported from the Late Miocene exposures in northern half of China. The pollen flora from the Bahe Formation of Shaanxi Province of Late Miocene is association with vertebrate fossil (Li, 1983; Qiu & Qiu, 1990) is also known. The discovery of the Late Miocene flora from the Daotaiqiao Formation of Huanan County, Heilongjiang Province of NE China is significant in Miocene environmental reconstruction and stratigraphic correlation for the Neogene of northern China.

All the specimens described in this paper are housed in the Nanjing Institute of Geology and Palaeontology, Academia Sinica.

STRATIGRAPHY

The fossil site is located at a site northeast to a small village of Sifangtai, Huanan County, Heilongjiang Province of NE China, about N. Lat. 46, E. Long. 131 (Text-figure 1). The climate is humid temperate with a precipitation of some 600 mm. Mean annual temperature is about 2.6°C. The mean monthly maximum temperature is 21.5°C (July), and the mean monthly minimum temperature is -19.4°C (January). The vegetation is of temperate mixed conifer and broad-leaved forest. The main trees of the forest are *Pinus koraiensis* (red pine) and *Tilia, Fraxinus,* etc.

The Cenozoic sediments in this area are deposited in a series of small basins extending in a



Text-figure 1

NE-SW direction, mainly consisting of the Quaternary, Neogene basalt and Neogene river-lacustrine mudstone, siltstone and sandstone, in descending order on the basement of Pre- Cenozoic granite. The deposits from which the present plant fossils are obtained is called as the Daotaiqiao Formation. This formation is composed of three parts : the uppermost is basalt; middle, the interbedded yellow and dark gray siltstone, mudstone and sandstone, about 12 m thick; the lower part is conglomerate. Our fossils are from the middle siltstone, mudstone and sandstone. The section of a placer gold well (the Fan's Well) representing the lithologic sequence of Daotaiqiao Formation is as follows :

Overlying strata : Quaternary

---------- Unconformity ----------

Dark grey basalt, 21.0 m thick.

Silver grey thick-bedded sandstone with a few sandy clay. 2.0 m thick.

Silver grey medium to coarse grained sandstone intercalated with thin-bedded silver grey clay. Fossil leaves are rare and badly preserved at the lower part. 5.5 m thick.

Yellowish green thin-bedded sandy clay, leaf fossils are rare. 0.5 m thick.

Dark grey clay, fine-bedded, containing rich plant fossils (leaves, cones, twigs, etc.). 3.5 m thick.

Yellowish green fine-bedded clay with abundant leaf fossils, 1.0 m thick.

Silver grey sand bed with pebbles, yielding elephant fossil, 1.6 m thick.

---------- Unconformity ----------

Pre-Tertiary granite

MATERIAL AND METHODS

The material for the present study is from four placer gold wells from where about thousand plant magafossil specimens and 14 pollen samples were collected. The photographs of plant megafossils have been taken in natural size. Some of the fossil leaves collected from the dark gray mudstone were prepared for further cuticle study. All cleaned samples were macerated in 10% HCl, followed by cold HF treatment to remove carbonates and silicates. Then each sample was oxidized in the Schultz Solution for few minutes. Organic and mineral material were separated by using a specific gravity heavy liquid ($ZnCl_2$). Residues were mounted on the 22 X 22 mm slides with glycerine jelly. The photographs of pollen grains have been taken under the Nikon microscope camera using common 21 Din (ASA 100) film.

RESULTS AND DISCUSSION

Fossil floras

Both plant megafossil and pollen floras are moderately abundant. They belong to the following main families and genera :

Table 1—List of mega- and micro-floras. The X sign marks the presence of fossil taxa

TAXA	MEGAFOSSIL FLORA	POLLEN FLORA
Aceraceae		
Acer	X	X
Alangiaceae		
Alangium	X	
Anacardiaceae		
Rhus	X	X
Betulaceae		
Alnus	X	X
Betula	X	X
Carpinus, Ostrya	X	X
Caprifoliaceae		
Weigela		X
Cercidiphyllaceae		
Cercidiphyllum	X	
Chenopodiaceae		X
Fagaceae		
Castanea	X	X
Fagus	X	X
Quercus	X	X
Ericaceae		
Rhododendron		X
Hamamelidaceae		
Shaniodendron	X	
Juglandaceae		
Carya		X
Juglans		X
Pterocarya		X
?Cyclocarya		X
Nyssaceae		
Nyssa	X	
Oleaceae		
Syringa	X	
Rosaceae		X
Malus	X	
Salicaceae		
Populus	X	
Salix	X	X
Saxifragaceae		
Hydrangea	X	
Tiliaceae		
Tilia		X
Ulmaceae	X	
Ulmus		X
Zelkova		X
Gramineae		X
Other monocots	X	X
Pinaceae	X	
Abies		X
Larix		X
Picea		X
Pinus	X	X
Tsuga		X
Taxodiaceae		X
Osmundaceae	X	X
Polypodiaceae		X

A. Plant megafossil—A preliminary examination of the specimens by Li HM and Leng Q shows that the flora contains at least 14 families, 20 genera and more than 30 species. Amongst them, the largest families are Fagaceae (including *Quercus, Fagus* and *Cas-*

PLATE 1 →

(All figures are at 800X)

1. *Larix* sp., Slide no. SF 5(2)
2. *Picea* sp., Slide no. SF 4(1)
3. *Pinus* sp., Slide no. SF 5(2)
4. *Tsuga* sp., Slide no. SF 5(1)
5. *Lycopodium* sp., Slide no. SF 5(1)
6. , *Juglans regia*-type, Slide no. SF 5(4)
7. *Carya* sp., Slide no. SF 5(1)
8. *Corylus* sp., Slide no. SF 5(2)
9. Undetermined triporate pollen (?Ulmaceae or ?Urticaceae), Slide no. SF 5(4)
10. *Carpinus* sp., Slide no. SF 5(2)
11. *?Potamogeton* sp., Slide no. SF 5(4)
12. Undetermined spore, Slide no. SF 5(2)
13. *Betula* sp., Slide no. SF 5(2)
14. *Alnus* sp., Slide no. SF 5(3)
15,16. *Quercus* sp., 15. Slide no. SF 5(4), 16.Slide no. SF 5(1)
17. *Tilia* sp., Slide no. SF 5(1)
18,19. *Ulmus* sp., 18. Slide no. SF 5(3), 19. Slide no. SF 5(2)
20,21. *Fagus* sp., Slide no. SF 5(2)
22. *Fagus* sp., Slide no. SF 5(3)

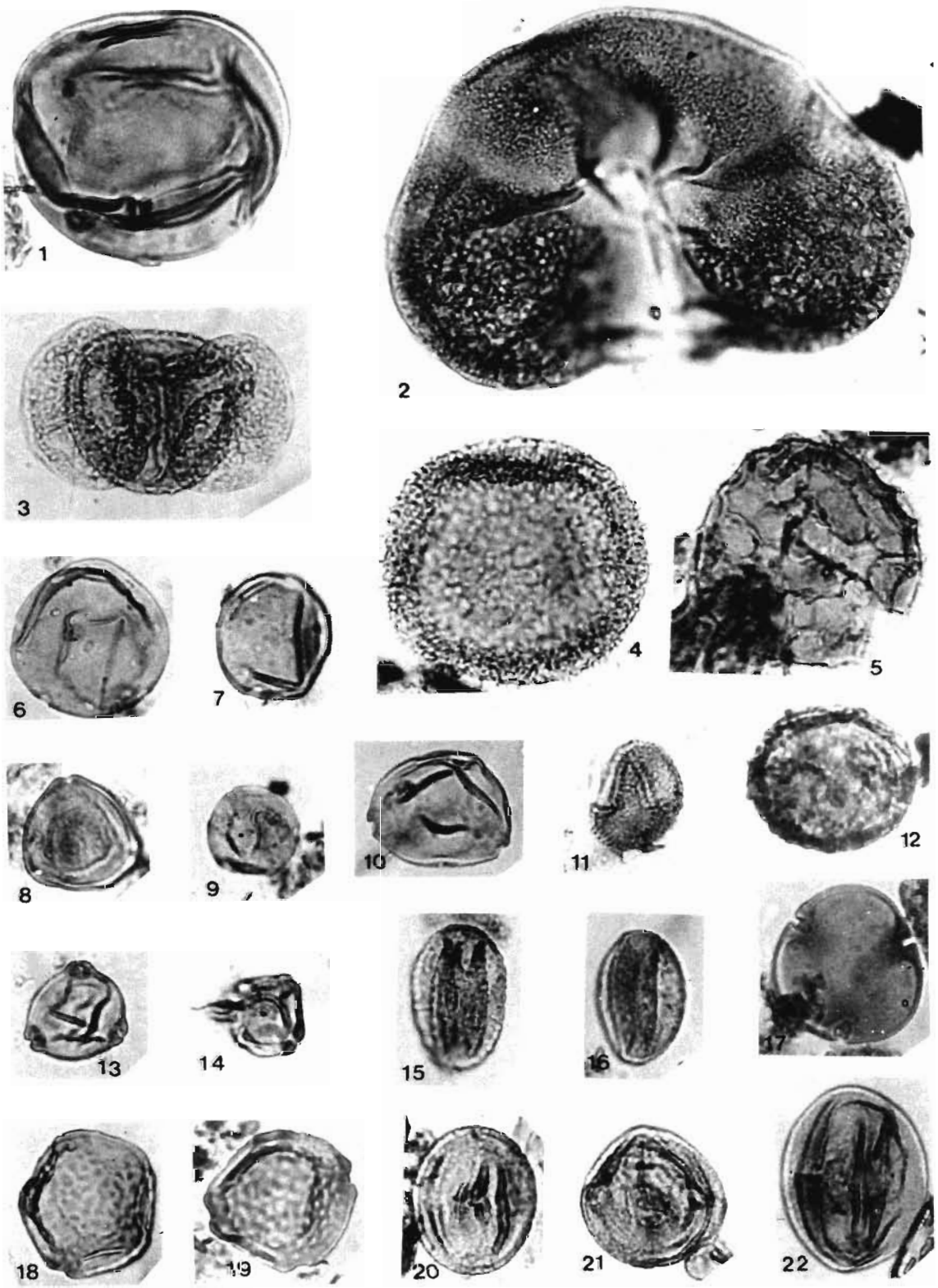


PLATE 1

tanea), and Betulaceae (including *Carpinus, Ostrya, Betula, Alnus*). Other important families are Pinaceae, Salicaceae, Aceraceae, Rosaceae, Cercidiphyllaceae, Alangiaceae, Oleaceae, Hamamelidaceae, Saxifragaceae, Anacardiaceae, Ulmaceae, and Osmundaceae. The preservation is quite satisfactory.

B. Pollen flora—The pollen flora is abundant and moderately diverse in contents. It comprises 12 families, 25 genera and more than 30 species. The flora is dominated by Betulaceae (*Betula, Alnus, Carpinus, Ostrya*) and Fagaceae (*Quercus, Fagus, Castanea*), with abundant Juglandaceae (*Pterocarya, Carya, Juglans*), Pinaceae (*Pinus, Picea, Tsuga, Larix, ?Abies*) and Ulmaceae (*Ulmus* and *Zelkova/Ulmus*). Other families are Salicaceae, Aceraceae, Rosaceae, Oleaceae and Cupressaceae. The pteridophytic spores are rare, mostly represented by Polypodiaceae and Osmundaceae.

FLORAL ANALYSIS

The characteristics of the flora are :

1. The main elements of both mega- and microflora are of Arcto-Tertiary floristic elements.
2. Amentiferous plants (i.e., Fagaceae, Betulaceae, Juglandaceae) and Pinaceae are the dominant members in the pollen flora. However, in plant magafossils Fagaceae, Betulaceae and Pinaceae are the dominant families, but Juglandaceae has not been found.
3. Terrestrial woody plants are much more than herbs. Aquatics are very rare. In pollen flora there are a number of undetermined moss spores and fresh water algae fossils, probably indicating a swamp environment.
4. At least 9 genera are exotic in the present flora occupying nearly 40 per cent of the fossil flora at generic level. The important elements of these exotic plants in the fossil flora and their modern distribution are listed below.

Tsuga—Modern *Tsuga* is distributed in mixed or conifer forest in the mountain areas of central and southern China.

Fagus—This genus is one of the leading members in the warm temperate and subtropical deciduous, and/or mixed evergreen and deciduous broadleaved forests in South and southern East China.

Castanea—This genus is widely distributed in South and southern East China, constituting one of the most common trees in the subtropical mixed evergreen and deciduous, and/or evergreen broadleaved forests. It also can be a tree component of the warm temperate deciduous forest.

Juglans regia type—In southern and central China, it is one of the tree elements in the warm temperate to subtropical deciduous, and/or mixed evergreen and deciduous broad-leaved forests.

Carya—In China, all the 2-3 species are distributed in the mixed evergreen and deciduous broadleaved forests in subtropical area.

Cercidiphyllum—China has only one species distributed mainly in the warm temperate and subtropical area.

GEOLOGICAL AGE OF THE FLORA

The flora is assigned to late Middle Miocene to Late Miocene on the basis of associated vertebrate fossils, i.e., elephant fossil (*Zygolophodon* sp.) (Qi, 1992) and fish fossil (Zhang Miman, oral communication, 1995). Li and Yang (1984) described an Early Miocene flora from Dunhua of Jilin Province, which contains abundant Taxodiaceae and *Woodwardia* showing much older appearance.

Liu (1988a) established a Neogene pollen sequence for northern China. His Zone 4 covered the Upper Miocene and Lower Pliocene. This zone was established on the pollen data mainly from the Bahe and Lantian formations of the Weihe Basin (Sun *et al.*, 1981) and the Huanghua area (Li & Liang, 1981). The vertebrate fossils from the Weihe Basin belong to the Late Miocene (Li *et al.*, 1984; Qiu & Qiu, 1990). The resemblance between Liu's Zone 4 and the present

PLATE 2 →

(All figures are in natural size)

1. *Salix* sp., Field no. SL1012
2. *Populus* sp., Field no. SX1002
3. *Castanea ungeri* Heer, Field no. SZ2015
4. *Carpinus miofangiana* Hu et Chaney, Field no. SZ2189
5. *Fagus antipofi* Heer, Field no. SF1026
6. *Quercus* sp., Field no. SF2064

PLATE 2

pollen flora indicates that the age of the pollen flora from Huanan is close to that of Zone 4. The differences between the two floras are : the present flora contains less xerophytes and thermophilic pollen, *e.g., Ephedra*, Chenopodiaceae and *Liquidambar*. These differences, in our opinion, are probably due to different latitudes and/or palaeoclimates of the two fossil localities.

PALAEOVEGETATION AND PALAEOCLIMATE

Floristically and numerically, both mega- and micro-fossils are dominated by deciduous Fagaceae, Betulaceae, Ulmaceae, Aceraceae and Pinaceae. Therefore, both mega- and micro-fossil floras reflect the existence of a mixed conifer and deciduous broad-leaved forest at the time of deposition. The main trees in this Miocene forest are deciduous comprising *Quercus, Fagus, Betula, Carpinus, Acer, Ulmus, Fraxinus,* etc., together with quite abundant Pinaceae trees. Shrubs in the forest are mainly of *Cercidiphyllum,* Ericaceae and possibly *Corylus,* and *Rhus*.

Based on the floral analysis, it has been concluded that a warm temperate type of climate was present during Miocene, rather than a temperate climate of today in this area. The mean annual temperature in Miocene was possibly 3°-5°C higher than that of the present time.

In composition, the restored vegetation for this area is obviously different from the modern one. The important trees in the modern mixed conifer and deciduous broad-leaved forest are *Pinus koraiensis, Abies holophylla, Tilia amurensis, T. mandshrica, Betula costada, Fraxinus mandshrica, F.* spp., *Carpinus cordata, Juglans mandshrica, Ulmus propinqua*. Under trees shrubs mainly are *Corylus mandshrica, Syringa reticulata* var. *mandshrica, Eleutherococcus senticuocus*. Vines mainly consist of different species of *Actinidia* and *Vitis amurensis, Schisandra chinensis, Celastrus*, etc. The difference between the extant and extinct floras reflects the difference in past and present climates (Wu, 1980).

As mentioned above, the important exotic elements in the fossil flora with no longer axis in the modern flora of the study area are distributed today in southern or central part of China in warm temperate to subtropical climatic condition. This indicates that the Miocene climate in the area of study was much warmer than today. It has been deduced that the Miocene climate in Huanan was probably similar to the present climate of the northern North China, i.e., Hebei Province or Shandong Province. The annual temperature was probably not lower than 6°-10°C.

In Late Miocene, an arid to semi-arid climate developed widely in the area of Northwest China, North China and western Norhteast China (Liu, 1988b). The Huanan flora shows that in eastern Northeast China the climate was humid at the time of deposition. Such climatic framework is quite similar to the modern one in the northern half of China.

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