

NEOGENE PALYNOLOGICAL SEQUENCE OF NORTHERN CHINA

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Summary

In the past three decades, many palynologists have contributed to our knowledge of spore-pollen content from Cenozoic sediments of China. However, most of them centered on the Early Tertiary and Quaternary, whereas study on the Late Tertiary palynology in our country was less attractive mostly because of our undue emphasis laid on its value in stratigraphic application and economic interest. As a matter of fact, from an evolutionary standpoint the Neogene palynofloras represent an important phase in Cenozoic floral history, which embrace a number of pioneers of modern plants and exhibit an embryonic framework of modern landscape. Moreover, a large collection and painstaking research on the palynofloras will certainly proliferate the applied value in a stratigraphic context. Therefore, the Neogene palynological study should share an equal importance in the investigation on Cenozoic palynofloras.

The present paper aims at summarizing the available data so as to present a primary palynological sequence for the Late Tertiary of northern China, which would serve as basis for the study on Neogene palynostratigraphy and palynofloral evolution of this region.

It should be noted that the term "northern China" used here is not corresponding to the traditional concept, but covers northern and north-western China. Floristically, it may be divided into three parts, i.e. the east, transition (or middle) and west areas. Palynological assemblages from 40 localities of these areas are adopted for the present study. All these localities shown on text-fig. 1 of Chinese text are listed below in the order of assemblage zone:

1—12, Assemblage Zone I

1. Wulougong, Hebei; 2. Hannaoba, Shanxi; 3. Tianzheng, Shanxi; 4. Xinhaote, Nei Mongol; 5. Guantao, Shandong; 6. Guzheng, Anhui; 7. Tianchang, Anhui; 8. Northern Jiangsu; 9. Hongtupou, Sichuan; 10. Minghe-Xining, Qinghai; 11. Qaidam, Qinghai; 12. Hunggar, Xinjiang.

13—21, Assemblage zone II

13. Shanwang, Shandong; 14. Bohai Sea; 15. Guzheng, Anhui; 16. Northern Jiangsu; 17. Weihe, Shaanxi; 18. Hongtupou, Sichuan; 19. Minghe-Xining, Qinghai; 20. Qaidam, Qinghai; 21. Junggar, Xinjiang.

22—29, Assemblage zone III

2. Liushanxiang, Shandong; 23. Bohai Sea; 24. Huanghua, Hebei; 25. Northern Jiangsu; 26. Weihe, Shaanxi; 27. Minghe-Xining, Qinghai; 28. Jiuquan, Gansu; 29. Changtai, Sichuan.

30—35, Assemblage zone IV

30. Bohai Sea; 31. Northern Jiangsu; 32. Weihe, Shaanxi; 33. Changtai, Sichuan; 34. Qaidam, Qinghai; 35. Jiuquan, Gansu.

36—40, Assemblage zone V

36. Jingle, Shanxi; 37. Yushe, Shanxi; 38. Weihe, Shaanxi; 39. Hongyuan, Sichuan; 40. Changtai, Sichuan.

According to relevant information from these areas, the palynofloras may be grouped into five assemblage zones which can be described in ascending order as follows.

ASSEMBLAGE ZONE I

This assemblage is from the Early Miocene sediment of northern China. The main localities include Wulougong of Hebei, Guantao of Shandong, Tianzheng of Shanxi, the Xining Basin of Qinghai, etc. The Assemblage zone is characterized by the rich presence of conifer pollen, associated with a number of amentiferous pollen.

In the palynoflora from Wulougong, gymnosperm pollen occupies the dominant position, amounting to 60—70% or even more, of the total assemblage and mainly consisting of *Piceapollenites* (about 20%), *Pinuspollenites* (about 20%), *Tsugaepollenites* (11—20%), and *Podocarpidites* (about 5%). Angiosperm pollen constitutes about 20—22% of the total, mainly composed of *Betulaceoipollenites*, *Juglanspollenites*, *Pterocaryapollenites*, *Caryapollenites*, *Alnipollenites*, *Tiliaepollenites* (1—2.8%) and *Ulmipollenites* (about 1%), with a few *Fagaceae* pollen. There is a very low percentage of herbaceous pollen and pteridophyte spores, such as *Chenopodipollis* and *Polypodiaceasporites*. The palynofloras from northern Anhui and Jiangsu are quite similar to that from Wulougong, but different in containing more *Fupingopollenites*, a form genus with unknown affinity.

In the transition area, a palynoflora from the upper part of the Xiejia Formation in the Xining-Minghe Basin, which has been assigned to Early Miocene based on the associated vertebrate fossil (Li and Qiu, 1980), is floristically similar to that from the east area. But angiosperm pollen constitutes about 60% of the total assemblage, with some xerophyte pollen of *Chenopodipollis* and *Meliaceoidites* (?*Nitraria*). Gymnosperm pollen mainly includes *Pinuspollenites*, *Piceapollenites*, *Tsugaepollenites*, etc., amounting to about 40% of the whole assemblage. In the west area, the Early Miocene palynoflora is represented by the Upper Ganchaigou Formation from the Qaidam Basin of Qinghai. It shares many common members with that of the Xiejia Formation, but contains more xerophyte pollen, such as *Nitrariadites*, *Ephedripites*, *Chenopodipollis* and *Compositae*, indicating an arid climatic condition existing in this area during that time.

ASSEMBLAGE ZONE II

This assemblage zone which is known in greater detail than any other Neogene assemblage zones, is well represented by the famous Shanwang flora, and has been dated the Middle or Early Middle Miocene in geological age. Shanwang, a small village in Shandong, is well-known for a nearby fossil locality yielding very rich and well-

preserved fossils of both animals and plants, based on which most geologists assigned the Shanwang Formation to Middle Miocene in age. In contrast with the old one, this assemblage zone is characterized by the high incidence of angiosperm pollen with a concomitant decline of gymnosperm pollen.

In the Shanwang palynoflora, the angiosperm pollen is very abundant and diverse, accounting for 79—98% of the total number, among which the four dominant forms, *Carpinipites*, *Quercoidites*, *Ulmipollenites* and *Caryapollenites* occupy 40—80% of the total, in addition to *Pterocaryapollenites*, *Juglanspollenites*, *Aceripollenites*, *Celtispollenites*, *Liquidambarpollenites*, etc. After a drop from above 60% to 2—20% of the total number, mainly includes *Pinuspollenites* and *Piceapollenites*, with the pteridophyte spores, mainly of *Polypodiaceasporites* occurring very scarcely. Very similar palynofloras obtained from Guantao of Shandong, northern Jiangsu and Anhui are different from the Shanwang palynoflora in containing more *Ceratopteris* and *Fupingopollenites* (often over 20% of the total).

A nearly contemporaneous palynoflora from the Lengshuigou Formation of the Weihe Basin (transition area) contains a large number of *Trapa*, *Fupingopollenites* with a minor number of *Chenopodipollis*, *Ephedripites*, etc. in addition to a number of amentiferous, *Ulmaceae* and coniferous pollen grains with a wide spatial distribution in northern China during the Miocene period.

Westward in the west area, the early Middle Miocene palynofloras from the Xining Basin of Qinghai, Kuqu Basin and Junggar Basin of Xinjiang share strong resemblances. The dominating angiosperm pollen of these microfloras occupies 60% of the total, with *Potamogeton* and *Chenopodipollis* often representing the main elements, although amentiferous pollen still exists in considerable abundance. The gymnosperm pollen, about 20—30% of the total, is mainly composed of *Pinaceae*, with only a few of pteridophyte spores coming into existence in most assemblages.

ASSEMBLAGE ZONE III

This assemblage zone is known from some

surface localities in northern China, representing late Middle Miocene palynofloras. In floristic features, this zone is similar to the preceding one in the presence of rich *Quercoidites*, *Caryapollenites*, *Juglanspollenites*, *Liquidambarpollenites*, *Tiliaepollenites*, *Carpinipites*, etc., but different in containing more herbaceous pollen referable to Chenopodiaceae, Compositae, Polygonaceae and Tiliaceae. Gymnosperm pollen is generally a little more than those of the older one.

Palynofloras from Changshanzi of Shandong, Huanghua of Hebei and the Bohai Sea (borecore sample) totally contain about 60% of angiosperm pollen which is mainly composed of *Ulmipollenites*, *Caryapollenites*, *Juglanspollenites*, *Liquidambarpollenites*, *Tiliaepollenites* and *Carpinipites* together with plentiful herbaceous pollen of *Chenopodipollis*, Compositae, Polygonaceae, Liliaceae, Graminidites, *Potamogeton*, Cruciferae, etc. In the Weihe Basin, the microflora from the fourth assemblage of the Gaoling Group was named the *Caryapollenites-Pinuspollenites-Ephedripites* Assemblage by Sun *et al.* (1980). As compared with the preceding assemblage from the same basin, some modifications can be easily observed. Ulmaceae, *Trapa* and amentiferous pollen continue to exist, but they are obviously reduced in number. A concomitant increase in *Ephedripites*, *Artemisia* and *Pinuspollenites* probably suggests a semi-arid climate which began to develop in the area. To the west of this area, the palynoflora from the Xining Basin of Qinghai is dominated by angiosperm pollen amounting to 95% of the total, among which *Chenopodipollis* occupies the first position (56%) while others include *Ulmipollenites* (12.5%), *Quercoidites* (13.5%), *Betulaceipollenites* (4%), *Potamogeton*, etc.

ASSEMBLAGE ZONE IV

In this assemblage zone, relatively few and discontinuous fossil records make it difficult to precisely date the microfloras; they have been provisionally assigned to the Late Miocene to Early Pliocene interval by the author. The Palynofloras had undergone an obvious alternation in composition. Throughout the whole northern China, this assemblage zone appears to represent

an arid or semi-arid climate phase. Xerophyte and herbaceous pollen frequently dominate the palynofloras, including *Chenopodipollis*, *Nitrariadites*, Polygonaceae, Compositae and *Ephedripites*. Towards the west, *Ephedripites* and *Nitrariadites* gradually increase in number, but tree pollen related to Ulmaceae, Pinaceae, Betulaceae and Fagaceae, etc. often occurs in low percentages.

From the Upper Member of the Minghuazheng Formation in the coastal area of the Bohai Sea, the Upper Yancheng Group of northern Jiangsu in the east area, the palynofloras are characterized by the dominance of such herbaceous pollen as *Chenopodipollis* (10—15%), Polygonaceae (10—15%), *Artemisia*, Compositae, Liliaceae, associated with a small number of the tree pollen of *Ulmipollenites*, *Quercoidites* and *Caryapollenites* with the existence of a few of *Pinuspollenites*, *Abietineapollenites*, *Piceapollenites* and *Ceratopteris* spores. In the transition area, the palynoflora from the Weihe Basin, which was named the *Ephedripites-Chenopodipollis-Pinuspollenites* assemblage by Sun *et al.* (1980), contains a large number of xerophyte pollen referable to Ephedraceae, Chenopodiaceae, Compositae (up to 60%) together with some scarce pollen of Ulmaceae, Juglandaceae, *Liquidamber* and Pinaceae. In the west area, the palynoflora from the Shizigou Formation of the Qaidam Basin is quite similar to those from the transition area, but differs in containing more abundant and diverse Compositae pollen and scarce Juglandaceae pollen.

ASSEMBLAGE ZONE V

This assemblage zone is the uppermost one of the Neogene palynological assemblage zones in northern China, belonging to Late Pliocene in geological age. It is different from the preceding assemblage zone, as xerophyte pollen is no longer the dominant element of the palynofloras in the east and transition areas. Instead, the pollen referred to Pinaceae, Ulmaceae, Compositae, Chenopodiaceae, etc. becomes the predominant members. Generally, this assemblage zone begins with those elements implying a cool climate phase, and then exhibits alternations of warm and cool elements, with a large amount of herbaceous pollen.

From the Zhangzun Formation of Shanxi (Li, 1983; Zhang, 1983) and the Rolgai area of Sichuan, the palynofloras contain very rich Pinaceae pollen, with some pollen of Compositae, Betulaceae, Ulmaceae and scarce spores of Polypodiaceae at their lowermost parts. Upwards, replacing the Pinaceae pollen, there appears a high incidence of Ulmaceae pollen with a number of Betulaceae, Chenopodiaceae, Juglandaceae and Compositae pollen grains in these microfloras. Towards the still upper part, such an alternation appears repeatedly. However, the Ulmaceae and Juglandaceae pollen occurs more abundantly at the lower part of the assemblage zone, but becomes less and less further upwards; concomitantly, Compositae, *Artemisia*, Chenopodiaceae and some other herbaceous pollen becomes more and more in number. Similar characteristics have been observed

in the coeval palynofloras from the Zhangjiapo Formation and the first to third formations of the Yongledian Group in the Weihe Basin of Shaanxi.

In the west area, this uppermost assemblage zone is dominated by *Artemisia*, Compositae, Chenopodiaceae, Pinaceae and Ephedraceae, with rare Betulaceae, Ulmaceae and Juglandaceae pollen. The alternations in composition are not so evident as in the other two areas.

There are some limitations in correlating the Neogene sporopollen-bearing sediments in northern China with the marine Neogene stratotypes in the Mediterranean area, or with those in the Paratethys area on the basis of Palynological evidence. The following is an indirect correlation table inferred with reference to Li *et al.* (1984)'s mammalian zones of Late Tertiary in China.

EPOCH	AGE	VERTEBRATE ZONES OF CHINA (Li <i>et al.</i> , 1984)	PALYNOLOGICAL SEQUENCE OF NORTHERN CHINA
PLIOCENE	Piacenzian	Yuhean	Assemblage zone V
	Zanclian	Jinglean	Assemblage zone IV
MIOCENE	Messinian	Baodean	
	Tortonian	Bahean	
	Serravallian	Tunggurian	Assemblage zone III
	Langhian	Shanwangian	Assemblage zone II
	Burdigalian	Xiejian	Assemblage zone I
	Aquitania		

Palynological studies have accumulated a wealth of information on the vegetational and climatic history of Late Tertiary in northern China. An implication of Neogene vegetation and climate is inferred based on the foregoing palynostratigraphic sequence, which reflects progressive floral and climatic changes in northern China throughout the Neogene time.

In general aspects, the Neogene floral history of the east and transition areas can be divided into three main stages, each representing a palaeovegetation type under a palaeoclimatic condition. The following table shows Neogene vegetations, climatic conditions and their changes in northern China:

EPOCH	STAGES	WEST AREA	TRANSITION AREA	EAST AREA
PLIOCENE	Third stage Late Pliocene Assemblage Zone V	Arid warm temperate steppe-parkland	Alternations of vegetation and climate	
	Second stage Late Miocene— Early Pliocene Assemblage Zone IV	Arid to semi-arid warm temperate parkland-steppe		
MIOCENE	First stage Early—Middle Miocene Assemblage Zones I—III	Arid warm temperate to subtropic steppe or/and parkland	Semi-arid warm temperate to subtropic parkland	Humid warm temperate to subtropic deciduous broad-leaved forest
			Humid warm temperate to subtropic mixed forest	

During the first stage, including Assemblage zones I-III of Early to Middle Miocene, the vegetation in general aspects was of the mixed forest type, mainly with conifers and amentiferous plants, indicating a humid warm temperate to subtropic climate. In Early Miocene the conifer forest, mainly of *Pinus*, *Picea*, *Abies*, *Tsuga*, etc. mixed with some broad-leaved trees, was distributed in most areas of northern China. In Middle Miocene, the deciduous broad-leaved forest was widely distributed and dominated by Ulmaceae, Betulaceae, Fagaceae, Juglandaceae, Hamameliaceae and Aceraceae, with a number of subtropic even tropic plants.

In the second stage, including Assemblage Zone IV of Late Miocene to Early Pliocene, the climate turned into a semi-arid to arid type from west to east, and prevailed throughout nearly the whole northern China. Correspondently, a great change in vegetation took place, in which the steppe or parkland vegetation mainly composed of Chenopodiaceae, Compositae, Polygonaceae, *Poa-*

mogeton, etc. covered most area of northern China, especially its western part, associated with a few of Ulmaceae, Betulaceae, Fagaceae trees and *Ephedra*, *Nitraria* shrubs.

Assemblage Zone V represents the third stage of Late Pliocene, which is characterized by the alternations of conifer forest and broad-leaved forest or steppe-forest implying a temperate type climate with alternations of warm and cool phases.

Whereas in the west area, almost all known palynological assemblages indicate an arid climate during the whole of the Neogene. The then vegetation was of the parkland and/or steppe type, mainly composed of Chenopodiaceae, Compositae, *Artemisia*, *Ephedra*, *Nitraria*, *Potamogeton*, Pinaceae, with a few of Ulmaceae, Betulaceae, Fagaceae, Juglandaceae, etc. Although in general tree pollen including amentiferous and Ulmaceae plants mostly occurs in the Miocene with herbaceous plants likely increasing upward, their changes in composition are not so evident as in the east and transition areas.