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A C T A
P A L A E O B O T A N I C A

Supplementum No. 5

PALYNOLOGY, PALAEOECOLOGY AND PALAEOCLIMATE OF THE MIOCENE SHANWANG BASIN, SHANDONG PROVINCE, EASTERN CHINA

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Kraków 2004

EDITORIAL OFFICE
W. Szafer Institute of Botany, Polish Academy of Sciences,
Lubicz 46, PL–31–512 Kraków, Poland

This volume was published with the financial support of the State Committee for Scientific Research

ISBN 83-89648-19-9
ISSN 0001-6594

Issued 15 November 2004

Printed in Poland: Drukarnia Kolejowa Kraków sp. z o.o., Bosacka 6, 31-505 Kraków

Acta Palaeobot. Suppl. 5: 3–95, 2004

Palynology, palaeoecology and palaeoclimate of the Miocene Shanwang Basin, Shandong Province, eastern China*

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Received 25 July 2003; accepted for publication 20 July 2004

ABSTRACT. The Early Middle Miocene Shanwang palynoflora has been subjected to a detailed systematic analysis including description and range determination of sporomorph taxa collected in 133 closely spaced (10–30 cm) and stratigraphically located samples from the Shanwang profile. The stratigraphic occurrence and distribution as well as the nearest living relatives of 108 pollen and spore taxa are documented. Using the coexistence approach quantitative palaeoclimatic data have been obtained from the palynoflora. These data indicate that there is no obvious change between high-resolution pollen samples, suggesting that stable climatic conditions persisted throughout the profile. Results indicate that the Shanwang biota had a mean annual temperature (MAT) of +15.6 – +17.2°C, in which temperature of the coldest month (TCM) was between +5.0 – +6.6°C, while temperature of the warmest month (TWM) was between +24.6 – +27.8°C. Mean annual precipitation (MAP) has been determined in the range of 1162–1281 mm, with precipitation of the warmest month (PwarmM) being 108–111 mm. Precipitation in the driest month (PDM) was 16–59 mm, with 148–180 mm occurring in the wettest month (PwetM). Relative humidity (RH) has been calculated as 72–75%. According to systems of recent climate classification, the Shanwang Miocene palaeoclimate is classified as Köppen's "Cfa climate" type that is warm, humid and temperate. In comparison to the climate of Shanwang today, the early Middle Miocene Shanwang palaeoclimate was significantly wetter and more equable, and with a warmer coldest month. Using cluster analysis of sporomorph distributions the palaeovegetation of the Shanwang profile has been reconstructed, indicating this was a mixed mesophytic forest that experienced little change throughout the period section. Small-scale changes in sporomorph composition suggest floral changes in the vicinity of the basin are most likely related to local changes in topography, and that these may have been fault controlled.

KEY WORDS: palynology, palaeoecology, palaeoclimate, coexistence approach, Miocene, Shanwang, China

CONTENTS

* Dissertation zur Erlangung des Grades eines Doktors der Naturwissenschaften, der Geowissenschaftlichen Fakultät, der Eberhard-Karls-Universität Tübingen, vorgelegt von Ming-Mei Liang aus Innermongolia. (This paper was presented by Ming-Mei Liang from Innermongolia as a dissertation for Ph.D. degree at the Eberhard-Karls-University Tübingen, Germany).

This project was supervised by Prof. Dr. Cheng-Sen Li and Prof. Dr. Volker Mosbrugger.

Financial support from NSFC Project (no. 30070056) of China, and the University Tübingen SFB 275 Project of Germany. It is part of the NECLIME programme (Neogene climate evolution in Eurasia).

INTRODUCTION

The Neogene represents a time interval in earth history during which climatic conditions were transitional between the Eocene globally warm greenhouse climate and the Quaternary glacial icehouse climate (White et al. 1997). This overall cooling trend has been documented from various data sources encompassing both oceanic and continental records (Savin et al. 1975, Savin 1977, Wolfe 1978, 1994, Mai 1995, Flower & Kennett 1994, 1995, Kennett 1996 and others) and presents a convincing model for global climate change through this period. In general, these data show that Neogene climates were generally warmer than those at the present time, with elevated CO_2 levels and unipolar glaciation. Nearly all of the fossil plant species present since the Oligocene, including those from the Neogene, are related to extant species (Axelrod 1960). From this relationship of past and present species, it is possible to reconstruct the past habitats and climates under which Neogene floras lived, to outline belts of Neogene vegetation, and to understand the evolution of modern vegetation distributions (Tanai 1972, Wolfe 1979, 1994, Mai 1995 and others).

There have been numerous studies of regional vegetation and related climatic changes throughout the Neogene. In general these analyses fit models of Neogene global temperature patterns that have been deduced from marine sources (Miller et al. 1987, Miller et al. 1991, Flower & Kennett 1995, Zachos et al. 2001 and others). China, which is situated at the eastern part of the Eurasian continent and including a diverse array of terrestrial habitats spanning several climatic zones, plays important roles in global climate patterns and distribution in the present day. However, detailed climatic information during the Neogene of China is currently lacking.

So far the majority of studies on the Neogene vegetation and climate in China are confined to syntheses of floristic composition. In several cases these are accompanied by qualitative palaeoclimatic deductions determined from the floral composition (e.g. Writing Group of Cenozoic Plants of China 1978, Li 1981, 1984, Guo 1983). The lack of quantitative data on Neogene vegetation and climates in China makes it difficult or impossible to test and compare floras globally with the Neogene global temperature pattern determined from the marine record.

Up to now, more than 100 research articles have been published on the Shanwang Formation, including palaeontological articles on palaeozoology, macro-palaeobotany and micropalaeontology (Yang & Yang 1994, Sun et al. 2002). In addition to these palaeontological investigations, studies on palaeomagnetism, radiometric dating, stratigraphy, petrology and basalts genesis and geochemistry have also been undertaken on the Shanwang fossiliferous section.

The Miocene-aged Shanwang biota in eastern China is remarkable for several reasons including its extraordinarily well-preserved fossils, its high taxonomic diversity in comparison to other Neogene sites, and its uninterrupted lacustrine sedimentation (Yang & Yang 1994). This combination of features allows detailed sampling of the biota from the Shanwang profile, and has led to the site becoming one of the most comprehensively known Miocene localities in the world. This fossil biota was deposited between 16.78 and 14.11 Ma (Chen & Peng 1985, Jin 1985, Zhu M. et al. 1985) and spans the time interval of the Neogene climatic optimum (~16 Ma) as well as the following climatic transition (~16 to ~14.8 Ma). The transition was marked by major short-term variations in global climate, east Antarctic ice sheet volume, sea level and deep ocean circulation (e.g. Flower & Kennett 1995). After this interval the global climate underwent rapid cooling and general deterioration into the icehouse climate of the Quaternary (e.g. Miller et al. 1991, Flower & Kennett 1995).

Pollen and spores as an effective palaeoclimatic and palaeoenvironmental proxy have been intensively used in Quaternary quantitative palaeoclimate reconstruction (e.g. Webb & Bryson 1972). However, the majority of previous Tertiary palynological analyses have used this proxy method for qualitative or semi-quantitative analyses of palaeoclimates. The development of the coexistence approach by Mosbrugger & Utescher (1997) allowed the successful quantification of Tertiary palaeoclimates using pollen and spores (e.g. Bruch 1998, Pross et al. 1998).

Bearing in mind the absence of quantitative data on Miocene palaeoclimates from China, the aims of this present investigation are fourfold:

– to detail the taxonomic composition of the Shanwang palynoflora,

– to undertake precise biostratigraphical dating of the sediments using palynological data,

– to apply the coexistence approach to a high-resolution pollen record to provide climatic parameters correlated with stratigraphic level, and

– to quantitatively reconstruct the palaeoecological changes in the Shanwang biota through time with the help of multivariate statistical methods.

GEOLOGY OF THE SHANWANG BASIN

GEOLOGICAL AND TECTONIC FRAMEWORK

The Shanwang Basin (36°N, 118°E) is a small NW-SE trending sedimentary basin that is approximately 600 m long and 500 m wide. The basin is located in the southern part of the Changle depression in the eastern part of the Sino-Korean platform (Fig. 1). The position and extent of the Changle depression is largely fault controlled, located to the north-

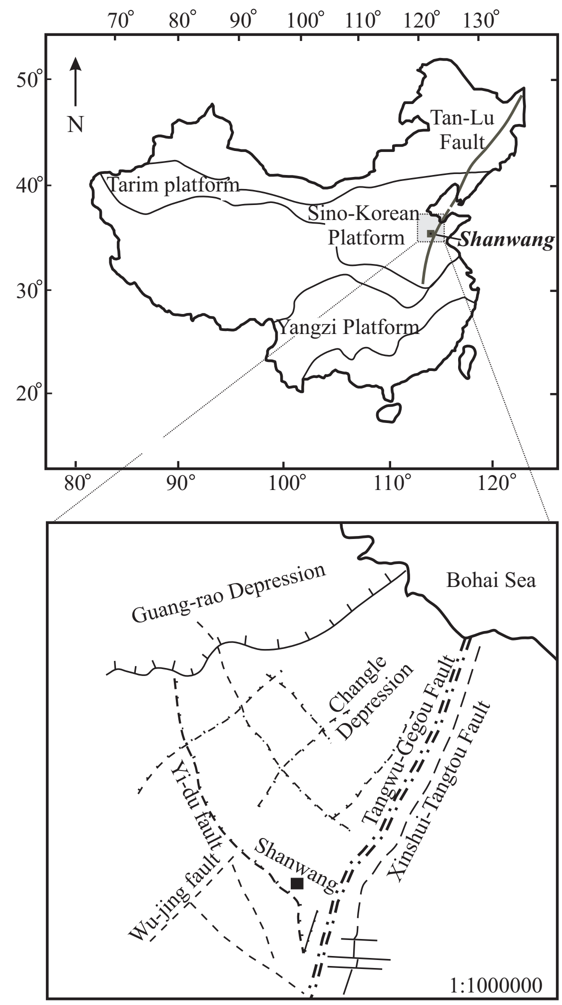

Fig. 1. Regional tectonic map of China (modified after Zhang et al. 1984) showing the position of the Shanwang area (top) and geological structure (after Sha 1978) of the Shanwang region (below)

east of the Luxi fault block and bounded to the east by the Tangwu-Gegou fault and to the west by the Yidu fault (Fig. 1). The Tangwu-Gegou fault is one of the central segments of the Tan-Lu fault in the Shandong Peninsula (Fig. 1, top), and in this region there also exist many smaller NE-NNE trending faults (Fig. 1, bottom) that are similarly associated with the Tan-Lu fault system (Shandong Seismogeological Survey Group 1974, Sha 1978, Luo et al. 1992). The Tan-Lu fault system is one of the main geological discontinuities in East Asia.

The Changle depression itself is a graben-rift type basin (Fig. 1) formed and developed during the tensional and fault related subsidence phase of the Tan-Lu fault system during the Early Cretaceous to early Palaeogene (Mesozoic-Cenozoic). Lacustrine sediments and alluvial facies were deposited between eruptions of the Neogene alkaline basaltic lithologies (Zhang & Shan 1994). The sediments of the Shanwang basin were formed under these conditions.

In the case of the Shanwang basin (Figs 2, 3), the sediments of the basin fill sequence rest unconformably on an olivine rich basaltic lava. This forms the base of the basin fill sequence. The basin fill sediments in the Shanwang basin are composed of conglomerates, sandstones, mudstones, shales, diatomites, oil-shales and interbedded basalts, with phosphorous nodules developing secondarily and post-depositional within the basin. These basin fill sediments are overlain by alkalic olivine basalts that mark the end of basinal deposition. The thickness of the upper basalt layer ranges from a few to 100 metres (Sha 1978, Li 1991).

SEDIMENTOLOGY AND LITHOSTRATIGRAPHY

In general, it is now accepted that the Neogene sequences of the Shanwang Basin can be subdivided into three formations. The lower part is the “Niushan Formation”, the middle part is the diatomite bearing and fossiliferous strata of the “Shanwang Formation”, and the upper part is the “Yaoshan Formation”. These sequences unconformably overlay Palaeogene strata (Shandong Regional Stratigraphic

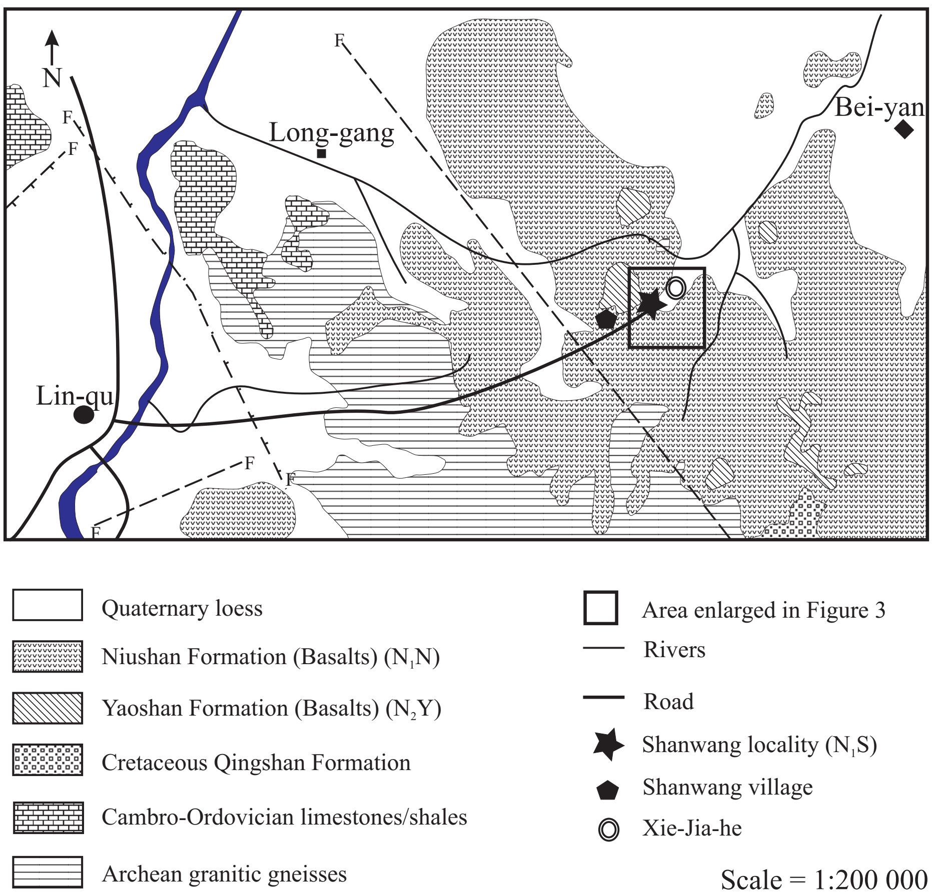

Fig. 2. Geological map of the Shanwang region (after Sha 1978)

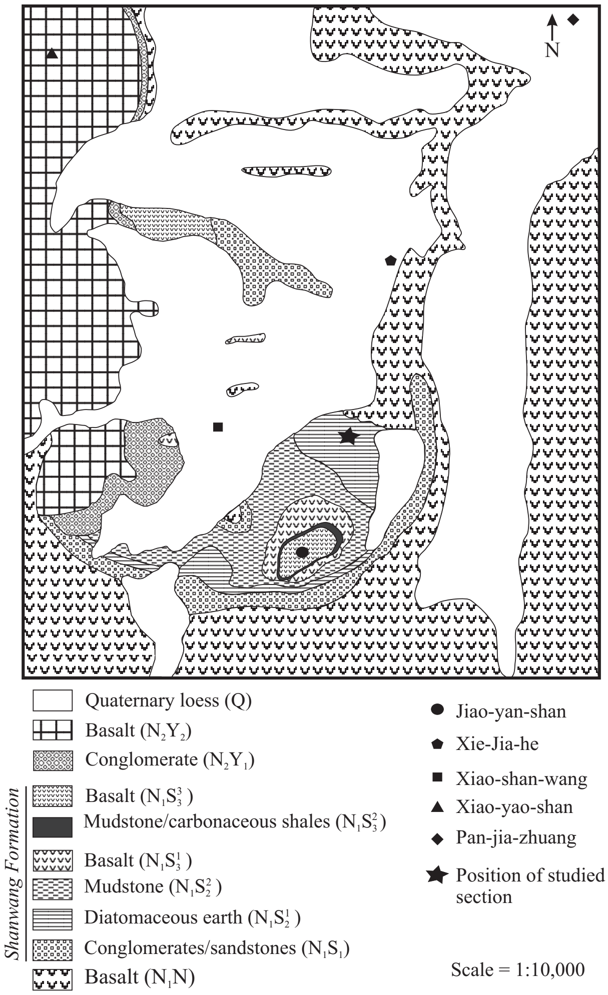

Fig. 3. Geological map of the Shanwang Basin (after Sha 1978)

Nomenclature 1978, Wang et al. 1981, Liu & Shi 1989, Yang & Yang 1994), or Archaean schist and gneiss of the Taishan Group (Li 1991). In general the Niushan Formation represents the basaltic sequence below the diatomaceous series of the Shangwang Formation and the Yaoshan Formation represents the basaltic sequence above it. However, neither the Yaoshan nor Niushan Formations have been formally delimited nor have they had type sections designated. This has resulted in different workers using these formation names to mean different things, and often based on different localized lithological variations (e.g. Wu & Chen 1978, Hong 1985, Li 1991, Zhang & Shan 1994). The present work mainly follows the sedimentary division by Sha (1978), Li (1991) and Li et al. (2000). In this account the lowermost basaltic layer is considered to be the Niushan Formation, and the uppermost basaltic and conglomerate layers to be the Yaoshan Formation. The sediments between these are considered to be the Shanwang Formation (Fig. 4).

The lowermost basaltic layer of Niushan Formation served as the basement rock for the early-period of the Shanwang lake, forming an impermeable barrier to water. The middle and upper basaltic layers from Shanwang Formation were formed during the evolution of the late-period Shanwang lake, with sediments accumulating above the second basalt while the third caps the sedimentary succession in the basin (Zhang & Shan 1994). The sedimentary history of the Shanwang lakes has been divided by Zhang & Shan (op.cit.) into an early-stage lake including those sediments between the lower and middle basalt, and a late-stage lake comprising those sediments between the middle and capping basalts of the Shanwang Formation (Fig. 4). This two-fold division has been followed in this investigation as it represents two distinct stages of Shanwang lake development and their different sedimentological histories.

SEDIMENTARY SUCCESSION OF THE EARLY-STAGE LAKE

The sedimentary succession of the early-stage lake constitutes the major part and the economically important diatomaceous sediments within the Shanwang Basin.

Following the basin history as outlined by Zhang & Shan (1994), in this investigation the early-stage lake has been divided into three units representing three major lithofacies reflecting the overall evolution of the early-stage lake (Fig. 4). Unit I represents the lake forming stage and initial stage of clastic sediment accumulation, unit II represents the sediments of the established lake stage (≈ flourish lake stage of Zhang & Shan 1994), while unit III represents stages of lake retrogression and the ultimate cessation of basin infilling in the early-stage.

Of these, unit II contains the majority of the economic diatomite horizons, has abundant mega-fossils and includes the section studied in this investigation (Fig. 4). This unit ranges in thickness from 6 to 27 m in different parts of the Shanwang basin (Sha 1978, Li 1991, Zhang & Shan 1994). In this unit the lake-shore facies consists of yellow-grey and yellow alluvial conglomerates, sandy conglomerates

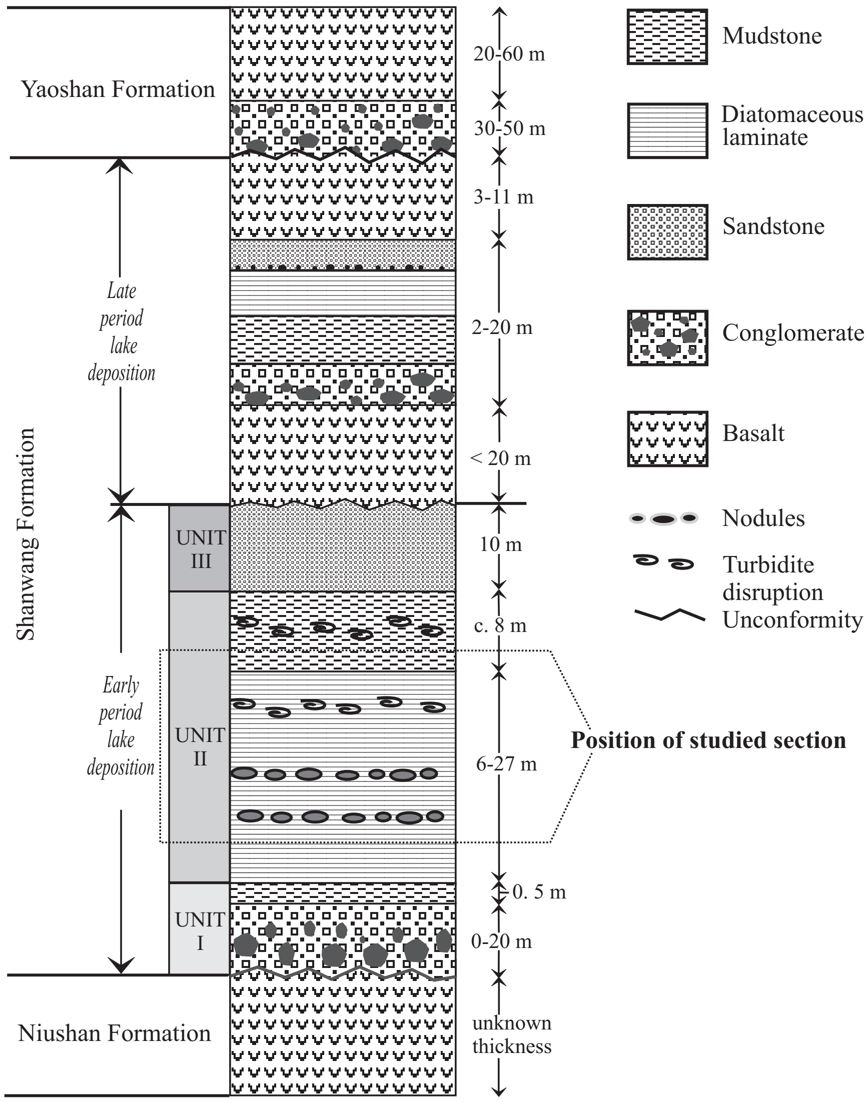

Fig. 4. Sedimentary succession of Shanwang Basin

and gravel-bearing sandstones. In contrast, the sediments away from the shoreline begin with a 5 m thick layer of yellow green and grey mudstones that alternate with diatom-bearing mudstones and are intercalated occasionally with diatom-rich mudstones (Zhang & Shan 1994). In this investigation diatomite layers have been observed to be annual laminations. Non-persistent layers of vivianite nodules and ferroan collinsite nodules occur infrequently within the diatomite layers. Occasionally turbidite layers and sedimentary layers with locally disrupted slump bedding occur within these layers. The presence of these irregularly dispersed nodule layers within the diatomaceous sequences indicates that the lake experienced cyclical changes in local environmental conditions. The top of this unit is marked by a yellow green, black green and black brown mudstone bed that is approximately 8 metres thick (Zhang & Shan 1994). This horizon possesses two thin turbidite layers at the base and is occasionally intercalated with diatomaceous mudstones. This bed is considered to have been deposited during the retrogressive stage of the early stage lake (Zhang & Shan op.cit.).

THE STUDIED SECTION

The lower unit of the Shanwang Formation approximating to Unit II of the early-stage Shanwang lake deposits was selected for study, focussing on the highly fossiliferous lacustrine sediments. The total thickness of the section is about 23 m which has been subdivided into 19 layers based on marked changes of lithological facies and texture

Table 1. Lithological features of the studied section (see also Fig. 5)

Layer	Thick-ness (m)	Lithology and fossils	Quantity of samples
19	1.8	Dark grey-green and grey-white mudstone with intercalated grey-yellow mudstone	4
18	1.5	Grey-black carbonaceous mudstone (seeds, fruits).	9
17	1.6	Black carbonaceous mudstone (seeds, fruits, leaves).	8
16	0.6	Grey-black muddy diatomite (seeds, fruits, leaves).	5
15	1.2	Grey muddy diatomite (leaves, fish).	6
14	0.5	Grey-black diatomaceous shale with black and white thin laminations (leaves, fish)	5
13	0.7	Grey muddy diatomite (leaves, fish)	5
12	0.55	Grey-black diatomaceous shale with black and white thin lamination (leaves, fish)	5
11	0.5	Grey diatomaceous shale with grey and black thin laminations. Yellow-green mudstone of 3 cm thick on the top, black diatomaceous shale of 10 cm thick with nodules at the base (leaves, fish)	5
10	0.3	Grey-black muddy diatomite (no fossil leaves)	3
9	1.5	Grey-black diatomaceous shale with black and white laminations (leaves, fish, insects, mammals)	9
8	2.5	Thickly-stratified grey muddy diatomaceous shale with black-white laminations, folded. Black diatomaceous shale with black nodules at 30 cm close to the base. Yellow-green mudstone of 20 cm thick at the bottom (leaves, fish, insects, mammals)	13
7	1.1	Grey-black muddy diatomaceous shale with black and white laminations. Nodule layers of 5-10 cm thick at the top, middle and bottom of the bed (leaves, fish, insects, mammals)	6
6	0.7	Dark grey-black diatomaceous shale with abundant nodules, yellow-green mudstone of 5 cm thick in the middle part (leaves, fish, insects, frogs)	5
5	1.6	Grey-white muddy diatomaceous shale with black-white lamination. Grey-black Fe-P nodule layer 20 cm thick in the middle and lower parts (leaves, fish, insects)	9
4	2.8	Grey-white muddy diatomaceous shale with black and white laminations. Grey-black muddy diatomaceous shale at 70 cm close to and at the base (leaves, fish, insects, mammals)	14
3	1.8	Yellow-green mudstone. Sand-conglomerate 40-60 cm thick in the middle part, black diatomaceous shale 10 cm thick in the lower part, nodules 5-10 cm diameter at the bottom	9
2	0.8	Grey-white diatomaceous shale with black and white laminations, black diatomaceous shale with nodules 10 cm thick at the base (leaves, fish)	6
1	1.1	Grey-white diatomaceous shale with black and white laminations. Diatomaceous shale 30 cm thick with black and white thin laminations at the top (leaves)	7

(Li et al. 2000). Table 1 gives brief descriptions of each of the 19 layers (as shown in Fig. 5) numbered consecutively from the bottom to the top of the section, and includes the thickness of the horizon and number of palynological samples collected.

MATERIAL AND METHODS

A total of 133 sediment samples were collected within the 22.95 m fossiliferous profile (Fig. 5). In order to obtain the high-resolution analyses of the palaeoecology and the palaeoclimatology required in this project, samples were obtained at intervals of between 10–30 cm with the precise sampling interval depending on the lithological characteristics of individual sedimentary units. At each sample level two separate samples were collected and labelled accordingly, with individual sample numbered successively. The majority of the lithologies sampled were mudstones, diatomaceous mudstone and diatomaceous shale. Samples were prepared in the Laboratory of the Departrment of Palaeobotany, Institute of Botany, Chinese Academy of Sciences, Beijging, using heavy liquid separation techniques (see below).

SPOROMORPH EXTRACTION: HEAVY LIQUID SEPARATION

Heavy liquid was prepared using 656 ml of HI (Hydroge iodide), 644 g of KI (Potassium iodide) and 145 g of Zn, with water added as the diluter to lower the density. Following the results of the experiments by Du & Chen (1990), the heavy liquid density was chosen at 1.8 g/cm^3.

Take 10 g samples and break into fine powder. Test every sample with a few spots of dilute hydrochloric acid (HCl, 1:1) to check for carbonate reaction. If necessary add cold hydrochloric acid (HCl) to dissolve calcium carbonate.

Immerse the sample in water, leave for at least 12 hours until it is entirely dispersed.

Boil the sample for 15 min, then add cold water. Centrifuge for 5 min at 2000 r.p.m. Add heavy liquid in the amount of ×2 sample volume. Stir vigorously then centrifuge for 30 minutes at 2500 r.p.m., repeat

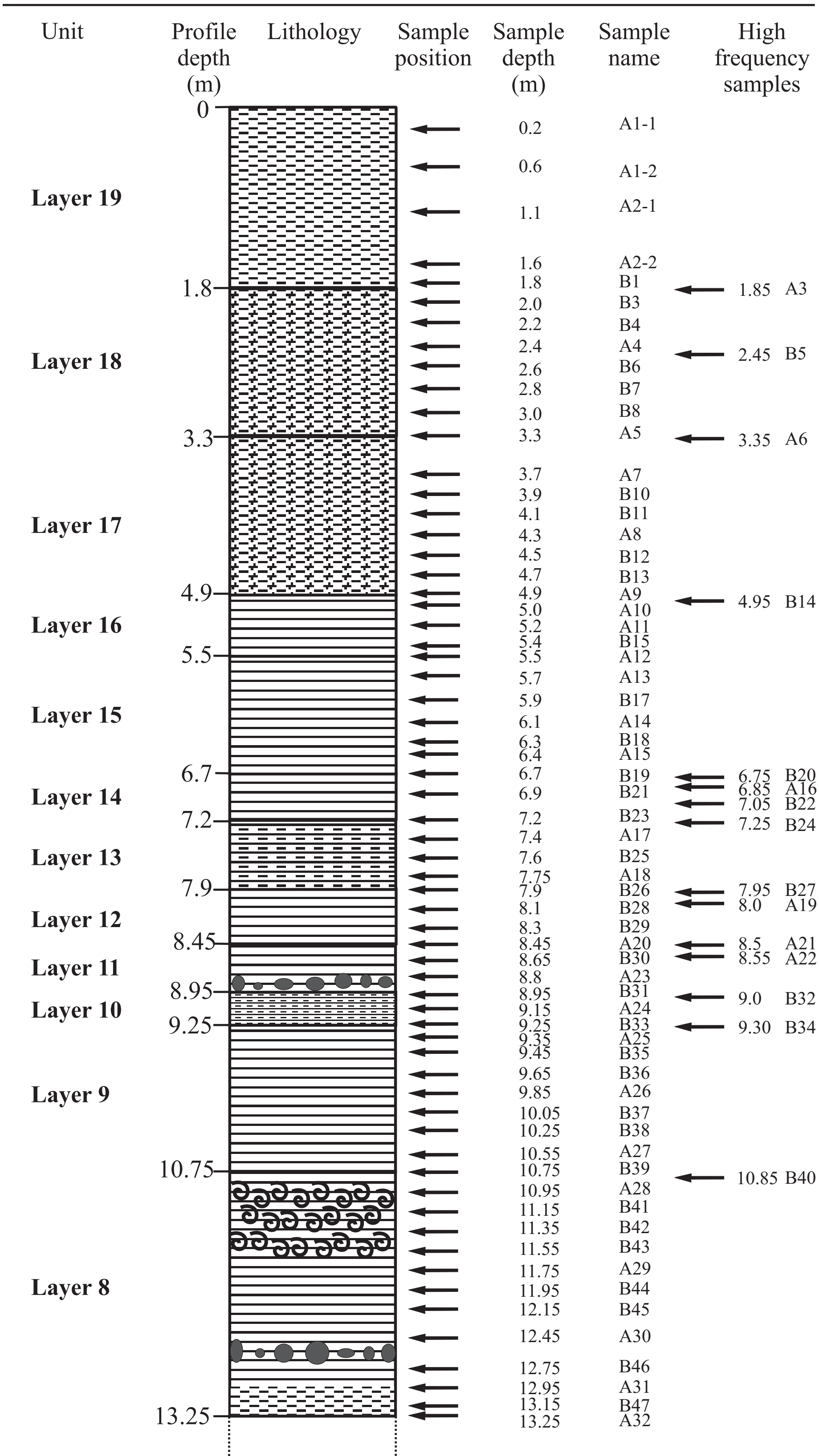

Fig. 5. Lithology of the studied section – sedimentary succession of Shanwang Basin

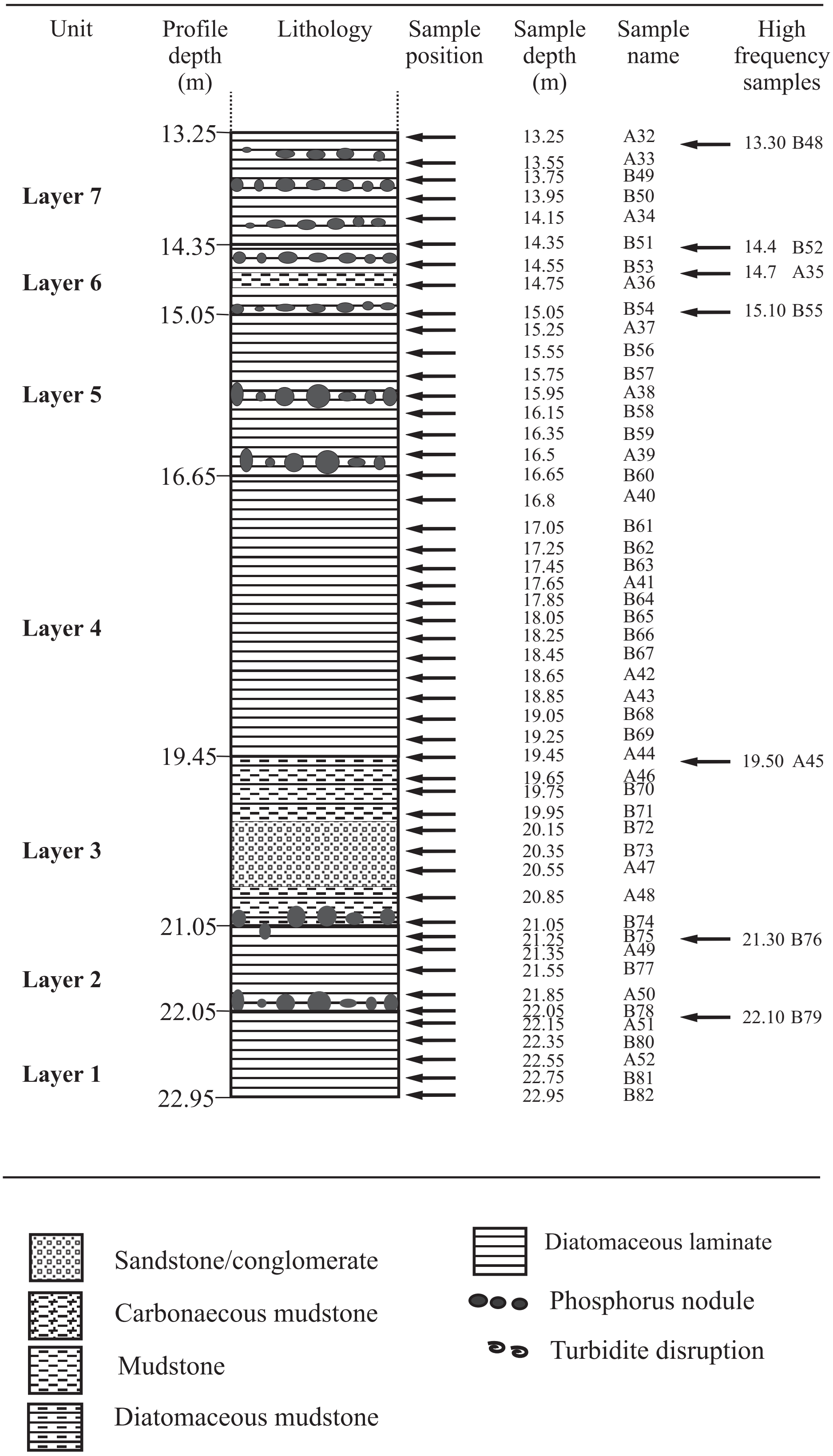

Fig. 5. Continued

this stage twice. Dilute the suspension in acidified water (acetic acid) with a density of less than 1.2 g/cm^3 and leave for 12 hours. Pipette out the liquid and move the residue to a 10 ml centrifuge tube and centrifuge.

Acetolysis was used to remove the remaining carbohydrates. The acetylation mixture (reagent) was prepared with acetic anhydrite $(CH_3CO)_2O$ and concentrated sulphuric acid (H_2SO_4) in the ratio of 9:1.

Wash the sample with glacial acetic acid and centrifuge for 5 minutes. Add 5 ml of fresh acetylation mixture and shake gently. Heat in 90°C water bath for 2 min while shaking frequently, then centrifuge for 5 minutes. Wash the sample with glacial acetic acid and centrifuge for 5 minutes. Wash sample in water twice, each time centrifuging for 5 minutes to concentrate samples. Dehydrate samples twice with 95% alcohol, centrifuging and decanting at each stage.

SLIDE MOUNTING AND PHOTOGRAPHY

For each sample two slides were mounted in glycerine jelly media. A total 266 fixed slides (2 slides from each sample) have been studied using an Olympus BX50 light microscope. A typical specimen of each morphological taxon has been photographed at several different optical focus levels including focus through the surface sculpture, exine structure, and aperture structure under 100/1.30 oil immersion. Phase contrast illumination has been used throughout the counting process and for photography. Co-ordinates on the plates relate the Olympus BX50 microscope in standard alignment. All slides are now stored at the Department of Palaeobotany, Institute of Botany, Chinese Academy of Sciences, Beijing.

EVALUATION AND COUNTING

Rarefaction curve techniques (Sanders 1968) as shown in Fig. 6 were used to estimate the relationship between taxon diversity and specimen frequency. This allows evaluation of how many pollen grains need to be counted so that the taxon trends become constant or stable (Sanders 1968, Raup 1975, Foote 1992). This curve represents the observed number of pollen grains along with the observed number of taxa. The shape of the rarefaction curve is a complex function of the "evenness" of taxon frequency and the average number of pollen grains per taxon. Since the pollen-taxon curves level out at about 150 pollen grains, counting at least 200 spores/pollen (excluding bisaccate pollen) per sample will include the vast majority of the total taxa. The abundance of pollen/spores varied, and in each slide between 200–350 was counted in order to provide a representative sample, and to search for rare taxa (refer to pollen diagram) for the count number of each sample). In a few slides with sparse sporomorphs this number was not attained.

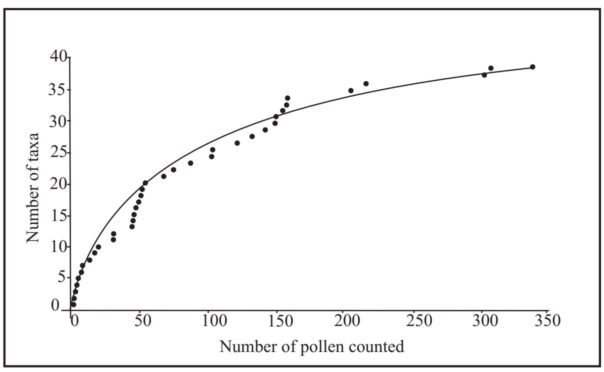

Fig. 6. Rarefaction curve for the Miocene Shanwang sporomorphs

METHODS OF PALAEOCLIMATE RECONSTRUCTION: THE COEXISTENCE APPROACH

In the present work the coexistence approach (Mosbrugger & Utescher 1997) has been used to derive the Shanwang Miocene palaeoclimate from its palynoflora. The coexistence approach is developed from the nearest living relative (NLR) approach and can provide quantitative palaeoclimatic parameters within a narrow interval using all the nearest living relatives of the fossil taxa (Belz & Mosbrugger 1994, Mosbrugger 1995, Mosbrugger & Utescher 1997, Utescher et al. 1997, Bruch 1998, Pross et al. 1998). For any fossil taxon that can have its nearest living relative determined, the fossil taxon's climatic requirements and climatic tolerances can be inferred from those of its nearest living relative (NLR). The interval of coexistence is the overlapping range within which all (or most) of the nearest living relatives can coexist, and is calculated for all climatic parameters under consideration (Mosbrugger 1995). The principle of coexistence analysis is shown in Fig. 7.

This method involves the use of the PALAEOFLORA databank (Mosbrugger & Utescher 1997) that contains over 1000 Tertiary taxa with their nearest living relatives and their climatic requirements for 10 different climate parameters (as listed in Tab. 2).

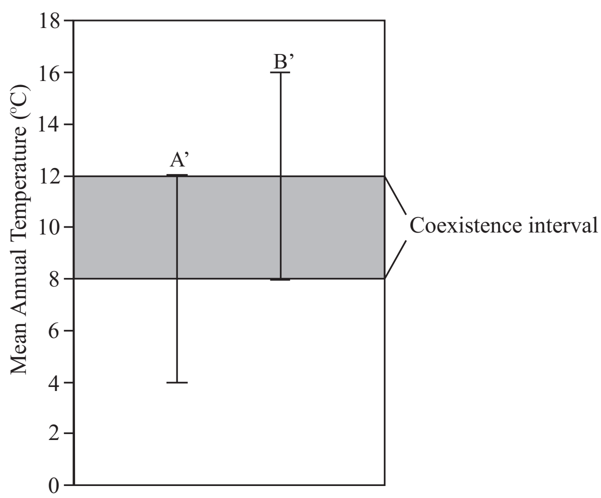

Fig. 7. Principle of the coexistence approach. The graph shows the mean annual temperature ranges that are tolerated by the nearest living relatives of two fossil taxa A' and B'. This is the temperature interval between 8 and 12 degrees in which both taxa could coexist (after Mosbrugger & Utescher 1997)

Table 2. List of climate parameters considered in coexistence analysis (after Mosbrugger & Utescher 1997, Bruch 1998)

Climate parameter	Abbreviation
Mean Annual Temperature	MAT
Temperature of the Coldest Month	TCM
Temperature of the Warmest Month	TWM
Difference of Temperatures of coldest and warmest month	DT
Relative Humidity	RH
Mean Annual Precipitation	MAP
Precipitation of the wettest Month	PwetM
Precipitation of the Driest Month	PDM
Difference of Precipitation of wettest and driest month	DP
Precipitation of the warmest Month	PwarmM

These data were collected from meteorological stations of the recent distribution areas of the plants. The ClimStat computer program is used to extract the necessary climate information from all of the taxa in the fossil flora under investigation, and from this the coexistence intervals for the 10 different parameters listed in Tab. 2 were calculated.

Mosbrugger & Utescher (1997) noted that an increasing taxonomic diversity improves climatic resolution and also permits the identification of inconsistencies between plant taxa. Bruch (1998) also noted that unsatisfactory or unresolved results were possible in samples of less than 10 climatically evaluable taxa. In accordance with the findings of Bruch, the 21 pollen samples from the Shanwang biota that contained less than 10 climatically evaluable fossil taxa have been excluded from coexistence analyses.

One of the main features of the coexistence approach is the use of presence/absence criteria for the fossil taxa rather than their relative abundance within the fossil flora (Mosbrugger & Utescher op.cit.). In this investigation all the fossil taxa for which nearest living relatives can be determined have been used to calculate coexistence intervals.

The width of the coexistence intervals determine the climatic resolution, the uncertainty is covered by the coexistence interval and no standard error is calculated in this method. As highlighted by Mosbrugger & Utescher (1997), sometimes not all NLR can coexist within a single coexistence interval but some form a "climatic outlier". Climatic outliers are related to one or more of the following factors: (1) the fossil taxon was misidentified; (2) the NLR of the fossil taxon was misidentified; (3) the climatic requirement of the NLR was not correctly determined and (4) the fossil taxon has different climatic requirements to its NLR. Taxa that form climatic outliers are excluded from the results as outlined by Mosbrugger & Utescher (1997).

METHOD OF PALAEOECOLOGICAL RECONSTRUCTION: CLUSTER ANALYSIS

The mathematical methods of cluster analysis have been described by several authors (Sokal & Sneath 1963, Deichsel & Trampish 1985, Kovach 1989, and others) and will not be repeated here. The result is a two-dimensional dendrograph, using Pearson product-moments correlation which represents the relationships between the taxa and is based only on the information contained in the percentage pollen counts.

Cluster analysis using the following parameters: Linkage rule: Ward's method; Distance measure: 1-Pearson r. A classification of the samples into groups is accomplished by arbitrarily choosing some specific level of similarity between groups. These groups are defined as those formed by linkages above the cut-off level.

In the present study, 108 taxa were originally recognized in the systematic analyses. Coniferous pollen with bisaccate morphologies are normally over represented in assemblages such as these were excluded from the cluster analysis. The form-taxa which are difficult to identify to their exact recent nearest living relatives, and the very rare taxa were also omitted from the cluster analysis. In total 70 taxa have been used in the cluster analysis. A mean similarity of 2.3, which divides the taxa into 4 groups, has been chosen.

SYSTEMATICS

GENERAL REMARKS

The systematic classification and the nomenclature of the palynomorphs basically follow the artificial morphological system established by Potonié (1956, 1958, 1960) and Thomson & Pflug (1953). Some taxa are modified according to the studies of Krutzsch (1962, 1966, 1970, 1971), Nagy (1969, 1985) and Thiele-Pfeiffer (1980). In each case the species names mainly express the morphological features of the taxa. Some pollen grains that have characters that can not be found in the available literature from fossil or extant species have been given numbers rather than new species names in this investigation.

In the synonymy lists, the first diagnosis, emendation, as well as subsequent cited quotations of species names and authors have been listed.

Circular sporomorphs have been measured across their diameters for sizes, whereas prolate sporomorphs have been measured in their polar axis × equatorial axis to determine their sizes. Since most of the sporomorphs have already been described by other authors in the existing literature, only a short description of the main features are given here, along with a citation for the literature containing the more detailed descriptions.

The general occurrence of the sporomorphs have been drawn mainly from the extensive studies of the European fossil microflora by numerous authors including, Thomson & Pflug (1953), Nagy (1969, 1985), Krutzsch (1962, 1966, 1970, 1971) and Thiele-Pfeiffer (1980) in addition to studies of Chinese spores and pollen fossil compiled by Song et al. (1999).

The botanical affinity of the sporomorphs is based on comparison with slides of modern taxa or using the established literature including Thomson & Pflug (1953), Nagy (1969), Krutzsch (1962, 1971), Gregor (1975), Thiele-Pfeiffer (1980) and Song et al. (1999). The representation of sporomorphs distribution within the Shanwang profile is shown on pollen diagram.

The following description of sporomorphs, the higher unit is arragned in the order of plant phylogenetic classification, the subunit is arranged by the sporomorph apertures characters, and the smallest unit is arranged by the alphabetical order of genera.

DESCRIPTION OF SPOROMORPHS

Divisio **TELMOPHYTA**
Subdivisio **PTERIDOPHYTINA**

Trilete spores

Genus ***Polypodiaceoisporites*** Potonié 1951 ex Potonié 1956

Type. *Polypodiaceoisporites speciosus* Potonié 1931 ex Potonié 1956

(1) ***Polypodiaceoisporites gracillimus*** Nagy 1963 ssp. ***granoverrucatus*** Krutzsch 1967

Pl. 1, fig. 1a, b

1967 *Polypodiaceoisporites gracillimus granoverrucatus* n. subfsp.; Krutzsch, p. 106, pl. 35, figs 11–14 (Germany, Upper Oligocene).

Size. 32–34 µm, $\bar{x}$ = 33 µm (n = 2)

Description. Zonal trilete spore, triangular outline in polar view, cingulum with slightly undulate margin. Surface verrucate sculpture.

Stratigraphic occurrence. From Oligocene to Miocene in Europe (Krutzsch 1967).

Occurrence in Shanwang. Rare.

Botanical affinity. Pteridaceae, probably *Pteris* L.

Monolete spores

Genus ***Laevigatosporites*** Ibrahim 1933

Type. *Laevigatosporites vulgaris* (Ibrahim 1932) Ibrahim 1933

(2) ***Laevigatosporites gracilis*** Wilson & Webster 1946

Pl. 1, figs 2a, b, 3a, b

1946 *Laevigatosporites gracilis* n. fsp.; Wilson & Webster, p. 273, 274, fig. 4/27 (USA, Montana Fort Union Coal).

1967 *Laevigatosporites gracilis* Wilson & Webster 1946; Krutzsch, p. 144, pl. 52, figs 1–11 (Germany, different source localities, Middle Oligocene to Pleistocene).

1978 *Polypodiaceaesporites gracilis* (Wilson & Webster 1946) Ke & Shi; IPEDPMPI-NIGPAS, p. 68, pl. 12, figs 1–3 (China, Bohai area, Early Tertiary).

1995 *Laevigatosporites gracilis* Wilson & Webster 1946; Ashraf & Mosbrugger, p. 126, pl. 9, fig. 9 (Germany, Lower Rhine Bay, Neogene).

Size. 25–27 µm, $\bar{x}$ = 26 µm (n = 2)

Description. Small, hyaline monolete spore, bean-shaped outline in equatorial view. Exine psilate.

Stratigraphic occurrence. From Middle Oligocene to Lower Pleistocene in central Europe (Kutzsch 1967), and the Tertiary of China (Song et al. 1999).

Occurrence in Shanwang. Very rare. Only two specimens have been found in the middle and upper part of the profile.

Botanical affinity. Polypodiaceae. Since different genera of the Polypodiaceae are hard to distinguish by their sporomorphs, it is difficult to assign this fossil form to any particular recent genus. Probably belongs to *Pronephrium* Presl (Thiele-Pfeiffer 1980).

(3) ***Laevigatosporites haardti*** (Potonié & Venitz 1934) Thomson & Pflug 1953 ssp. ***haardti*** Krutzsch 1967

Pl. 1, fig. 5

1934 *Sporites haardti* n. sp.; Potonié & Venitz, p. 13, pl. 1, fig. 13 (Germany, Ville, Beissels mine, Rhine browncoal, Miocene).

1952 *Polypodiaceae sporites haardti* Potonié; Meyer, p. 30, pl. I, fig. 12 (Germany, Wackersdorf, Miocene).

1953 *Laevigatosporites haardti* Potonié & Venitz 1934; Thomson & Pflug, p. 59, pl. 3, figs 27–38 (Germany, different source localities, Palaeocene, Eocene, Oligocene and Miocene).
1967 *Laevigatosporites haardti* (Potonié & Venitz 1934) Thomson & Pflug 1953 ssp. *haardti*; Krutzsch, p. 146–148, pl. 52, figs 12–21 (Germany, different source localities, Oligocene, Miocene, Pliocene and Pleistocene).
1980 *Laevigatosporites haardti* (Potonié & Venitz 1934) Thomson & Pflug 1953 ssp. *haardti* Krutzsch 1967; Thiele-Pfeiffer, p. 111, 112, pl. 5, figs 1, 2 (Germany, Oder/Wackersdorf, Miocene).
1984 *Laevigatosporites haardti* (Potonié & Venitz 1934) Thomson & Pflug 1953 ssp. *haardti* Krutzsch 1967; Mohr, p. 51 (Germany, Frechen Mine, Upper Miocene).
1995 *Laevigatosporites haardti* (Potonié & Venitz 1934) Thomson & Pflug 1953 ssp. *haardti*; Ashraf & Mosbrugger, p. 126, 127, pl. 9, figs 8, 11 (Germany, Lower Rhine Bay, Neogene).
2001 *Laevigatosporites haardti* (Potonié & Venitz 1934) Thomson & Pflug 1953; Stuchlik et al., p. 56, pl. 35, figs 13–36; pl. 36, figs 1–6 (Poland, Palaeogene–Neogene).

Size. $\bar{x} = 35$ µm (n = 1)

Description. Small, hyaline monolete spore, bean-shaped outline in equatorial view. Exine psilate. According to Krutzsch (1967) this differs from *Laevigatosporites gracilis* in size (usually over 30 µm), and shape (larger than semi-hemisphere).

Stratigraphic occurrence. Throughout the Tertiary in Europe (Thomson & Pflug 1953, Krutzsch 1967); from Upper Cretaceous to Tertiary (mainly in Tertiary) in China (Song et al. 1999).

Occurrence in Shanwang. Very rare.

Botanical affinity. Polypodiaceae. Probably belongs to *Pronephrium* Presl (Thiele-Pfeiffer 1980).

Genus ***Verrucatosporites*** Pflug & Thomson in Thomson & Pflug 1953

Type. *Verrucatosporites alienus* (Potonié 1931) Thomson & Pflug 1953

(4) ***Verrucatosporites favus*** (Potonié 1931) Thomson & Pflug 1953 ssp. ***favus*** Krutzsch 1967

Pl. 1, figs 4a, b, 6a, b, 7

1931c *Polypodii* (?)-*sporonites favus* n. sp.; Potonié, p. 556, pl. 3 (Germany, Ville, Beisselsmine, Miocene).
1952 *Polypodiaceaesporites alienus* Potonié; Meyer, p. 30, pl. 1, fig. 15 (Germany, Wackersdorf, Nordfeld open peat mine, Miocene).
1953 *Verrucatosporites favus* (Potonié 1931) n. comb.; Thomson & Pflug, p. 60, pl. 3, figs 52–55; pl. 4, figs 1–4 (Germany, different source localities, from Eocene to Miocene).
1967 *Verrucatosporites favus* (Potonié 1931) Thomson & Pflug 1953 ssp. *favus*; Krutzsch, p. 184, pl. 68, figs 1–8 (Germany, different source localities, from Middle Oligocene to Miocene).
1978 *Polypodiisporites favus* Potonié 1931; IPEDP-MPI-NIGPAS, p. 70, 71, pl. 11, figs 7, 8, 10 (China, Bohai areas, Early Tertiary).
1980 *Verrucatosporites favus* (Potonié 1931) Thomson & Pflug 1953 ssp. *favus* Krutzsch 1967; Thiele-Pfeiffer, p. 113, pl. 5, fig. 9 (Germany, Oder/Wackersdorf, Miocene).
1984 *Verrucatosporites favus* (Potonié 1931) Thomson & Pflug 1953; Mohr, p. 53, pl. 5, figs 3, 9 (Germany, Frechen, Fortuna Garsdorf, Miocene).
1995 *Verrucatosporites favus* (Potonié 1931) Thomson & Pflug 1953 ssp. *favus*; Ashraf & Mosbrugger, p. 133, pl. 10, figs 8–10 (Germany, Lower Rhine Bay, Neogene).
2001 *Verrucatosporites favus* (Potonié 1931) Thomson & Pflug 1953; Stuchlik et al., p. 60, pl. 41, figs 1–5 (Poland, Middle Miocene).

Size. 45×35 µm (n = 3)

Description. Monolete spore, bean-shaped outline in equatorial view. Surface covered by densely spaced flat verrucae.

Stratigraphic occurrence. In central Europe from Middle Eocene to Pliocene (Krutzsch 1967), and throughout the Tertiary of China (Song et al. 1999).

Occurrence in Shanwang. Very rare. Only several specimens in the whole profile have been recorded.

Botanical affinity. Polypodiaceae, *Polypodium* L., probably *P. vulgare* L. (Planderová 1990) or several other similar recent species cited by Thiele-Pfeiffer (1980).

Subdivisio **GYMNOSPERMOPHYTINA**

Inaperturate pollen grains

Genus ***Inaperturopollenites*** Pflug & Thomson in Thomson & Pflug 1953

Type. *Inaperturopollenites dubius* (Potonié & Venitz 1934) Thomson & Pflug 1953

(5) ***Inaperturopollenites concedipites*** (Wodehouse 1933) Krutzsch 1971

Pl. 3, figs 2, 3

1933 *Cunninghamia concedipites* n. sp.; Wodehouse, p. 495, pl. 19 (USA, Colorado, Green River Oil Shales, Middle Eocene).

1971 *Inaperturopollenites concedipites* (Wodehouse 1933) n. comb.; Krutzsch, p. 204, pl. 65, figs 1–33 (Eastern Germany, different source localities, from Middle Oligocene to Pliocene).
1978 *Taxodiaceaepollenites hiatus* (Potonié) Kremp 1949; IPEDPMPI-NIGPAS, p. 95, pl. 29, figs 1–7, 9, 10 (China, Coastal region of Bohai area, Early Tertiary).
1980 *Inaperturopollenites concedipites* (Wodehouse 1933) Krutzsch 1971; Thiele-Pfeiffer, p. 118, 119, pl. 7, figs 2, 3 (Southern Germany, Oder/Wackersdorf, Miocene).
1996 *Inaperturopollenites concedipites* (Wodehouse 1933) Krutzsch 1971; Ashraf & Mosbrugger, p. 9, pl. 2, fig. 15 (Germany, Lower Rhine Bay, Neogene).
2002 *Inaperturopollenites concedipites* (Wodehouse 1933) Krutzsch 1971; Stuchlik et al., p. 50, 51, pl. 71, figs 9–29 (Poland, Miocene).

Size. 30–35 µm, $\bar{x} = 32$ µm (n = 5)

Description. Circular to elliptic pollen grains, often split and folded in a characteristic manner. A single small papilla is often at the middle of the plane. Exine psilate to microgemmate.

Stratigraphic occurrence. From Eocene to Pliocene (Krutzsch 1971), and frequently from Oligocene to Pliocene.

Occurrence in Shanwang. Sporadic.

Botanical affinity. Taxodiaceae, *Glyptostrobus* Endl., or *Taxodium* Rich. (Krutzsch 1971).

Genus ***Sequoiapollenites*** Thiergart 1937

Type. *Sequoiapollenites polyformosus* Thiergart 1937

(6) ***Sequoiapollenites largus*** (Kremp 1949) Manum 1962

Pl. 3, fig. 6

1949 cf. *Cryptomeria – Poll. largus* n. sp.; Kremp, p. 58, pl. 5, fig. 30 (Poland, Miocene).
1962 *Sequoiapollenites largus* Kremp 1949; Manum, p. 43 (combined type *largus* to *Sequoiapollenites*, Krutzsch 1971, p. 210).
1971 *Sequoiapollenites largus* (Kremp 1949) Manum 1962; Krutzsch, p. 208, pl. 67, figs 1–27 (Eastern Germany, Poland, different source localities, Upper Oligocene to Pliocene).
1978 *Sequoiapollenites polyformosus* Thiergart 1937; IPEDPMPI-NIGPAS, p. 94, pl. 29, figs 22, 24–30 (China, Coastal region of Bohai area, Early Tertiary).
2002 *Sequoiapollenites largus* (Kremp 1949) Manum 1962; Stuchlik et al., p. 53, 54, pl. 74, figs 8–15 (Poland, Oligocene–Pliocene).

Size. 35×25 µm (n = 1)

Description. Broadly elliptic pollen grain, short straight papilla. Papilla and its surrounding-arms smooth. Exine on papilla is thinner than that on arms. Exine on proximal side is thick. Surface coarsely gemmate.

Stratigraphic occurrence. From the Upper Oligocene to Pliocene in central Europe (Krutzsch 1971). Noted in several localities in China from Eocene to Oligocene.

Occurrence in Shanwang. Only a single specimen recorded in this study.

Botanical affinity. Taxodiaceae, *Metasequoia* Miki ex Hu & Cheng, *Cryptomeria* D. Don, *Sequoia* Endl. (Thiele-Pfeiffer 1980).

Genus ***Sciadopityspollenites*** Raatz 1937 ex Potonié 1958

Type. *Sciadopityspollenites serratus* (Potonié & Venitz 1934) Raatz 1937 ex Potonié 1958

(7) ***Sciadopityspollenites serratus*** (Potonié & Venitz 1934) Raatz 1937 ex Potonié 1958

Pl. 3, figs 5, 8

1934 *Sporites serratus* n. sp.; Potonié & Venitz, p. 13, pl. 1, figs 6, 7 (Germany, Ville, Lower Rhine Bay, Miocene).
1937 *Sciadopitys-pollenites serratus* Potonié & Venitz 1934; Raatz, p. 13, pl. 1, fig. 16 (Germany, Upper Lusatia, Muskauer Bogen, Miocene).
1953 *Monocolpopollenites serratus* (Potonié & Venitz 1934) n. comb.; Thomson & Pflug, p. 64, pl. 4, figs 67–74 (Germany, Ville, Wallensen in Hils, Miocene to Pliocene).
1980 *Sciadopityspollenites serratus* (Potonié & Venitz 1934) Raatz 1937; Thiele-Pfeiffer, p. 118, pl. 7, fig. 1 (Germany, Oder/Wackersdorf, Miocene).
1996 *Sciadopityspollenites serratus* (Potonié & Venitz 1934) Raatz 1937; Ashraf & Mosbrugger, p. 12, pl. 3, figs 11, 12 (Germany, Lower Rhine Bay, Neogene).
2002 *Sciadopityspollenites serratus* (Potonié & Venitz 1934) Raatz 1937 ex Potonié 1958; Stuchlik et al., p.44, 45, pl. 56, figs 1–6; pl. 57, figs 1–7 (Poland, Neogene).

Size. 30–43 µm, $\bar{x} = 37$ µm (n = 4)

Description. Circular pollen grain often with secondary crease. Characteristical hollow verrucae densely distributed on the surface.

Stratigraphic occurrence. From Upper Eocene to Upper Pliocene in central and eastern Europe (Krutzsch 1971). From Late

Cretaceous to Eocene in China (Song et al. 1999).

Occurrence in Shanwang. Very rare. Only several specimens have been found at the top and in the middle part of the profile.

Botanical affinity. Taxodiaceae, *Sciadopitys* Sieb. & Zucc. It is very similar to *Sciadopitys verticillata* Sieb. & Zucc. (Thiele-Pfeiffer 1980).

Genus ***Zonalapollenites*** Pflug in Thomson & Pflug 1953

Type. *Zonalapollenites igniculus* (Potonié 1931) Thomson & Pflug 1953

(8) ***Zonalapollenites igniculus*** (Potonié 1931) Thomson & Pflug 1953

Pl. 2, fig. 1a, b

1931c *Sporonites igniculus* n. sp.; Potonié, p. 556, fig. 2 (Germany, Ville, Miocene).

1953 *Zonalapollenites igniculus* (Potonié, 1931) n. comb.; Thomson & Pflug, p. 66, pl. 4, figs 75–79 (Germany, Brown coal from Hils Wallensen, Middle to Upper Pliocene).

1971 *Zonalapollenites igniculus* (Potonié, 1931) Thomson & Pflug 1953; Krutzsch, p. 138, pl. 37, figs 1–23, tab. 8 (Germany, Poland, different source localities, from Oligocene to Pliocene).

1978 *Tsugaepollenites igniculus* f. *major* and f. *minor*; IPEDPMPI-NIGPAS, p. 91, 92, pl. 19, figs 1–4, 8–14 (China, Bohai areas, early Tertiary).

1996 *Zonalapollenites igniculus* (Potonié 1931) Thomson & Pflug 1953; Ashraf & Mosbrugger, p. 3, pl. 1, figs 5–7 (Germany, Lower Rhine Bay, Neogene).

2002 *Zonalapollenites igniculus* (Potonié 1931) Thomson & Pflug 1953; Stuchlik et al., p. 35, pl. 46, figs 6–9 (Poland, Miocene to Pliocene).

Size. 45–50 µm, $\bar{x} = 47$ µm (n = 4)

Description. Small non-spined inaperturate pollen grain, strong and wide zonal frill-liked collar. Surface of grain with hollow irregular verrucae. Detailed description provided by Krutzsch (1971).

Stratigraphic occurrence. From Middle Oligocene to Pliocene, especially abundant in Middle and Upper Oligocene (Krutzsch 1971).

Occurrence in Shanwang. Sporadic.

Botanical affinity. Pinaceae, *Tsuga* Carr. (Krutzsch 1971).

(9) ***Zonalapollenites maximus*** (Raatz 1937) Krutzsch 1971 ex Ziembińska-Tworzydło 1974

Pl. 2, fig. 6

1937 *Tsuga-pollenites igniculus* Potonié f. *maximus* n. f.; Raatz, p. 15, pl. 1, fig. 13 (Germany, Muskau, Lower Miocene).

1971 *Zonalapollenites maximus* (Raatz 1937) n. comb.; Krutzsch, p. 138, Tab. 8, pl. 36, figs 1–8 (Germany, different source localities, Oligocene and Pliocene).

1974 *Zonalapollenites maximus* (Raatz 1937) Krutzsch 1971; Ziembińska-Tworzydło, p. 352, 353, pl. 12, fig. 2 (South-western Poland, Neogene).

1978 *Tsugaepollenites igniculus* f. *major* and f. *minor*; IPEDPMPI-NIGPAS, p. 91, 92, pl. 19, figs 1–4, 8–14 (China, Bohai areas, early Tertiary).

1984 *Zonalapollenites maximus* (Raatz 1937) Krutzsch 1971; Mohr, p. 58, pl. 7, figs 2, 3 (Germany, Frechen, Fortuna Garsdorf, Miocene, Pliocene).

1996 *Zonalapollenites maximus* (Raatz 1937) Krutzsch 1971; Ashraf & Mosbrugger, p. 4, pl. 1, fig. 8 (Germany, Lower Rhine Bay, Neogene).

2002 *Zonalapollenites maximus* (Raatz 1937) Krutzsch 1971; Stuchlik et al., p. 35, 36, pl. 47, figs 1–5 (Poland, Neogene).

Size. 70–100 µm, $\bar{x} = 80$ µm (n = 4)

Description. Large non-spiny inaperturate pollen grains, strong and wide zonal frill-liked collar, surface of grain with hollow irregular verrucae. According to Krutzsch (1971), the difference from *Zonalapollenites igniculus* is the size in which the border for distinguishing these two species is 60–65 µm.

Stratigraphic occurrence. From Upper Middle Eocene to Pliocene (Krutzsch 1971).

Occurrence in Shanwang. Frequent but not numerous in the whole profile.

Botanical affinity. Pinaceae, *Tsuga* Carr., *T. canadensis* Carr. (Krutzsch 1971).

(10) ***Zonalapollenites minispinus*** Krutzsch 1971

(Without figure)

1971 *Zonalapollenites minispinus* Krutzsch n. sp.; Krutzsch, p. 168, pl. 51, figs 9–12 (Germany, Waidmannsheim, Upper Miocene).

Size. 45–57 µm, $\bar{x} = 50$ µm (n = 4)

Description. Small spined inaperturate pollen grain without frill-like collar. For detailed description see Krutzsch (1971).

Stratigraphic occurrence. Only previously known in the Upper Miocene from several localities in Germany (Krutzsch 1971).

Occurrence in Shanwang. Sporadic.

Botanical affinity. Pinaceae, *Tsuga* Carr. (Krutzsch 1971).

(11) ***Zonalapollenites spinosus*** (Doktorowicz-Hrebnicka 1964) Ziembińska-Tworzydło 1974

Pl. 2, figs 4a, b, 5

1971 *Zonalapollenites spinulosus* n. sp.; Krutzsch, p. 148, pl. 41, figs 1–10 (Germany, Torgau Axien drill, Lower Miocene; Wilsnack drill 2, Middle Miocene; Hodonin drill, B15, Pannon, Dremmen 2, Lower Rhine area and scratch 3 Oberzella / Werra, Upper Pliocene).

1974 *Zonalapollenites spinosus* (Doktorowicz-Hrebnicka) comb. n.; Ziembińska-Tworzydło, p. 353, 354, pl. 12, fig. 1 (South-western Poland, Neogene).

1978 *Tsugaepollenites spinulosus* (Krutzsch 1971) Ke & Shi; IPEDPMPI-NIGPAS, p. 92, 93, pl. 19, figs 15, 16 (China, Coastal region of Bohai, Early Tertiary).

1978 *Zonalapollenites spinulosus* Krutzsch 1971; Hochuli, p. 68, pl. 9, fig. 4 (Slovakia, central and western Paratethys, Oligocene).

2002 *Zonalapollenites spinosus* (Doktorowicz-Hrebnicka 1964) Ziembińska-Tworzydło 1974; Stuchlik et al., p. 38, 39, pl. 52, figs 1–4 (Poland, Neogene).

Size. 70–85 μm, $\bar{x} = 76$ μm (n = 4)

Description. Inaperturate pollen grain with sparsely distributed spine, zonal frill-liked collar, surface of grain with hollow irregular verrucae. According to Krutzsch (1971), sparse spine can distinguish this species from *Zonalapollenites maximus*. For complete details see Krutzsch (1971).

Stratigraphic occurrence. From Upper Oligocene to Upper Pliocene in central Europe (Krutzsch 1971), and throughout the Tertiary of China (Song et al. 1999).

Occurrence in Shanwang. Frequent but not numerous through the entire profile.

Botanical affinity. Pinaceae, *Tsuga* Carr., *Tsuga diversifolia* Mast. (Krutzsch 1971).

Saccate pollen grains

Genus ***Abiespollenites*** Thiergart 1937 ex Potonié 1958

Type. *Abiespollenites absolutus* Thiergart 1937 ex Potonié 1958

(12) ***Abiespollenites*** div. sp.

Pl. 3, fig. 4

Size. 140–85×80–60 μm, $\bar{x} = 123 \times 70$ μm (n = 8)

Description. Large bisaccate pollen grains. Air-sacci are larger than hemispherical shape. Proximal body wall thinning next to the sacci. The body is oblate or circular. According to Krutzsch (1971), it belongs to "silvestroid" type. For detailed description see Krutzsch (1971).

Stratigraphic occurrence. Northern Hemisphere from Mesozoic to Cenozoic, mainly in the Cenozoic (Song et al. 1999).

Occurrence in Shanwang. Sporadic.

Botanical affinity. Pinaceae, *Abies* Mill., or *Keteleeria* Carr. (Krutzsch 1971).

Genus ***Piceapollis*** Krutzsch 1971

Type. *Piceapollis praemarianus* Krutzsch 1971

(13) ***Piceapollis*** sp.

Pl. 3, fig. 1a, b

Size. 115–60×85–40 μm, $\bar{x} = 88 \times 63$ μm (n = 9)

Description. Large bisaccate pollen grains. Air-sacci are smaller than hemispherical shape. Sacci not constricted at their point of attachment to the body. Body is oblate. Distal body wall between the sacci psilate or faintly granulate. According to Krutzsch (1971), it belongs to "haploxylonoid" type. For detailed description see Krutzsch (1971).

Stratigraphic occurrence. World-wide from Mesozoic to Cenozoic (Song et al. 1999).

Occurrence in Shanwang. Frequent throughout the profile but not in great numbers.

Botanical affinity. Pinaceae, *Picea* Dietr. (Krutzsch 1971).

Genus ***Pityosporites*** Seward 1914

Type. *Pityosporites antarcticus* Seward 1914

(14) ***Pityosporites*** div. sp.

Pl. 2, figs 2a, b, 3a, b

Size. 50–85×32–60 μm, $\bar{x} = 66 \times 45$ μm (n = 7)

Description. This is a collective category for small or medium size bisaccate pollen grains. Air-sacci are more or less larger than hemispherical shape. The body is from circular to oblate. Proximal body wall shows a slightly undulating outer layer. Conspicuous verrucae on the inner side of the distal body wall between the sacci (*Haploxylon*), or no conspicuous verrucae, but psilate or granulate on the inner side of the distal body wall between the sacci (*Diploxylon*). According to Krutzsch (1971), it belongs to the "silvestroid", "haploxylonoid" types, or the transitional types between them. For detailed description see Krutzsch (1971).

Stratigraphic occurrence. World-wide from Mesozoic to Cenozoic (Song et al. 1999).

Occurrence in Shanwang. Frequent but not in large numbers throughout the entire profile.

Botanical affinity. Pinaceae, *Pinus* L. (Krutzsch 1971).

Genus ***Podocarpidites*** Cookson 1947

Type. *Podocarpidites ellipticus* Cookson 1947

(15) ***Podocarpidites*** sp.

(Without figure)

Size. 60–42×35–25 µm, $\bar{x}$ = 51×30 µm (n = 6)

Description. Small or medium size bisaccate pollen grain. Magnisaccate air-sacci are larger than hemispherical shape. The body is from circular to oblate. According to Krutzsch (1971), it belongs to "podocarpoid" type. For detailed description see Krutzsch (1971).

Stratigraphic occurrence. World-wide from Mesozoic to Cenozoic (Song et al. 1999).

Occurrence in Shanwang. Sporadic.

Botanical affinity. Podocarpaceae, *Podocarpus* L'Hér. ex Pers. (Krutzsch 1971).

Monosulcate pollen grains

Genus ***Cycadopites*** Wodehouse 1933 ex Wilson & Webster 1946

Type. *Cycadopites follicularis* Wilson & Webster 1946

(16) ***Cycadopites microfollicularis*** Krutzsch 1970

Pl. 4, fig. 1a, b

1970 *Cycadopites microfollicularis* n. sp.; Krutzsch, p. 94, pl. 18, figs 9–11 (Germany–Holland border, Höngen drill, Pliocene).

Size. 32×18 µm (n = 1)

Description. Elongated, elliptic monosulcate pollen grain with a conspicuous furrow. Furrow is more or less closing in the middle and opening at the ends. Exine psilate or finely granulate. For more detailed description see Krutzsch (1970).

Stratigraphic occurrence. Neogene in central Europe (Krutzsch 1970).

Occurrence in Shanwang. Only several specimens in the upper part of the profile.

Botanical affinity. Unknown. Pollen of this kind belongs to *Ginkgo* L., *Cycas* L., or other taxa with monosulcate pollen forms (Krutzsch 1970).

(17) ***Cycadopites*** cf. ***minimus*** (Cookson 1947) Krutzsch 1970

Pl. 3, figs 10, 11a, b

1970 *Cycadopites* cf. *minimus* (Cookson 1947) n. comb.; Krutzsch, p. 95, pl. 18, figs 13, 14 (Germany, Laussig drill, Upper Oligocene).

Size. 24×18 µm (n = 2)

Description. Oval monosulcate pollen grain, with a narrow furrow. Exine tectate, perforate. For detailed description see Krutzsch (1970).

Stratigraphic occurrence. Upper Oligocene in Germany (Krutzsch 1970).

Occurrence in Shanwang. Very rare, only several specimens in the middle and lower parts of the profile.

Botanical affinity. Unknown. This kind of pollen is produced by plants including *Ginkgo* L., *Cycas* L., or other unknown plants producing monosulcate pollen forms (Krutzsch 1970).

Polyplicate pollen grains

Genus ***Ephedripites*** Bolkhovitina 1953 ex Potonié 1058

Type. *Ephedripites mediolobatus* Bolkhovitina 1953

(18) ***Ephedripites* (*Distachyapites*) *cheganicus*** (Shakmundes 1965) Ke & Shi 1978

Pl. 3, fig. 13

1965 *Ephedra cheganica* Shakmundes n. sp.; Shakmundes, p. 221, pl. 2, figs 1–4 (Russia, West Siberia, Lower Oligocene).
1978 *Ephedripites* (*Distachyapites*) *cheganicus* (Shakmundes 1965) Ke & Shi 1978; IPEDPMPI-NIGPAS, p. 97, pl. 32, figs 1–3 (China, Coastal region of Bohai area, Early Tertiary).

Size. 48×28 μm (n = 1)

Description. Broadly elliptic polyplicate pollen grain with 6–8 colpi almost running into the poles. Colpi with irregular margins forming zigzag-lines between colpi, reaching to the poles. Clear branch from zigzag-lines reaching to the pollen margin and forming wavy outline.

Stratigraphic occurrence. Frequent from Eocene to Oligocene, occasional from Miocene to Pliocene in China (Song et al. 1999).

Occurrence in Shanwang. Sporadic.

Botanical affinity. Ephedraceae, *Ephedra* L. (Song et al. 1999).

(19) ***Ephedripites* (*Distachyapites*) *fusiformis*** (Shakmundes 1965) Krutzsch 1970

Pl. 3, fig. 12a, b

1965 *Ephedra fusiformis* Shakmundes n. sp.; Shakmundes, p. 222, pl. III, figs 1–6 (Russia, West Sibirian lowland, Middle Oligocene).
1970 *Ephedripites* (*Distachyapites*) *fusiformis* (Shakmundes 1965) n. comb.; Krutzsch, p. 160, pl. 46, figs 1–32 (Germany, different source localities, from Upper Eocene to Miocene).
1976 *Ephedripites* (*Distachyapites*) *fusiformis* (Shakmundes 1965) Krutzsch 1970; Song et al., p. 28, pl. 5, fig. 21 (China, Yunnan, Mesozoic to Early Tertiary).

Size. 58×20 μm (n = 1)

Description. Slenderly elliptic polyplicate pollen grain with 6–8 colpi running into the poles. Colpi with irregular margins forming zigzag-lines between colpi, reaching to the poles. Zigzag lines with branch. Different from *Ephedripites* (*Distachyapites*) *cheganicus* in its narrow contour and smooth outline. For more detailed description see Krutzsch (1970).

Stratigraphic occurrence. From Upper Eocene to Lower Miocene in central Europe, frequent in Oligocene (Krutzsch 1970). Frequent in Eocene and Oligocene in China, occasional in Miocene and Pliocene (Song et al. 1999).

Occurrence in Shanwang. Sporadic.

Botanical affinity. Ephedraceae, *Ephedra* L. (Krutzsch 1970).

(20) ***Ephedripites* (*Distachyapites*) *fushunensis*** Sung & Tsao 1980

Pl. 3, fig. 7a, b

1961 *Ephedripites* (*Distachyapites*) fsp.; Krutzsch, pl. 7, figs 137–139 (Kazakhstan, Karatau, Lower/Middle Eocene).
1980 *Ephedripites* (*Distachyapites*) *fushunensis* Sung & Tsao; Song & Cao, p. 4, pl. 2, figs 18, 19 (China, Fushun coal mine, Palaeogene).

Size. 40×20 μm (n = 1)

Description. Elliptic polyplicate pollen grain with 3–5 colpi running into the poles. Pronounced zigzag-lines with dense branches forming the wavy outline. Differs from *Ephedripites* (*Distachyapites*) *cheganicus* in its small size.

Stratigraphic occurrence. Frequent in Eocene and Oligocene, occasional in Miocene and Pliocene in China (Song et al. 1999). In Kasachstan, Karatau in Lower/Middle Eocene (Krutzsch 1961).

Occurrence in Shanwang. Only one specimen from the upper part of the profile.

Botanical affinity. Ephedraceae, *Ephedra* L. (Song et al. 1999).

(21) ***Ephedripites* (*Ephedripites*) *wolkenbergensis*** Krutzsch 1961

Pl. 3, fig. 14

1961 *Ephedripites* (*Ephedripites*) *wolkenbergensis* n. fsp.; Krutzsch, p. 23, fig. 5, pl. 2, figs 33–36 (Germany, Wolkenberg , Upper Oligocene–Lower Miocene).
1970 *Ephedripites* (*Ephedripites*) *wolkenbergensis* Krutzsch 1961; Krutzsch, p. 164, pl. 48, figs 22–28 (Germany, different source localities, from Middle Oligocene to Upper Pliocene).
1981 *Ephedripites* (*Ephedripites*) cf. *wolkenbergensis* Krutzsch 1961; Song et al., p. 100, pl. 31, figs 22, 28 (China, Jiangsu, Tertiary).
1985 *Ephedripites* (*Ephedripites*) *strigatus* Brenner 1968; Zhu et al., p. 97, pl. 34, figs 26–28 (Northwestern China, Chaidamu Basin, Tertiary).

Size. 45–47×26 μm, $\bar{x}$ = 46×26 μm (n = 3)

Description. Elliptic polyplicate pollen grain with 10–12 colpi reaching to the poles. Colpi with smooth stright edges, not forming zigzag-lines as well as branches. Smooth outline. For more detailed description see Krutzsch (1970).

Stratigraphic occurrence. From the Upper Oligocene to the Upper Pliocene in central Europe (Krutzsch 1970) and throughout Tertiary in China (Song et al. 1999).

Occurrence in Shanwang. Sporadic.

Botanical affinity. Ephedraceae, *Ephedra* L. (Krutzsch 1970).

Subdivisio **ANGIOSPERMOPHYTINA**

Monocolpate pollen grains

Genus ***Arecipites*** Wodehouse 1933

Type. *Arecipites punctatus* Wodehouse 1933

(22) ***Arecipites convexus*** (Thiergart 1937) Krutzsch 1970

Pl. 3, fig. 9

1937 *Sabal-pollenites convexus* n. sp.; Thiergart, p. 308, pl. 24, fig. 15 (Germany, Miocene).

1970 *Arecipites convexus* (Thiergart 1937) n. comb.; Krutzsch, p. 103, 104, pl. 21, figs 20–31 (Germany, different source localities, Miocene).

1985 *Arecipites longicolpatus* Krutzsch 1970; Song et al., p. 133, pl. 46, figs 11–13 (China, Longjing Structural Area in the Shelf Basin of the East China Sea Region, Upper Eocene to Pliocene).

Size. 30×22 µm (n = 1)

Description. Monosulcate pollen grain in oval outline. Exine tectate, reticulate, with columellate structure in the wall. Muri delicate, lumina polygonal, not decrease towards the sulcus.

Stratigraphic occurrence. Middle Miocene in Germany (Krutzsch 1970); Upper Eocene to Pliocene in China (Song et al. 1999).

Occurrence in Shanwang. Only single specimen.

Botanical affinity. Palmae. According to Krutzsch (1970), other families Amaryllidaceae, Liliaceae, Araceae and Butomaceae are also possible.

Monoporate pollen grains

Genus ***Graminidites*** Cookson 1947 ex Potonié 1960

Type. *Graminidites media* Cookson 1947 ex Potonié 1960

(23) ***Graminidites gramineoides*** (Meyer 1956) Krutzsch 1970

(Without figure)

1952 *Gramineenpollen*; Meyer, p. 36, pl. III, fig. 55 (Germany, Wackersdorf, Miocene).

1956 *Monoporopollenites gramineoides* n. gen. n. sp.; Meyer, p. 111, 128, pl. 4, fig. 29 (Germany, Wackersdorf, Miocene).

1970 *Graminidites gramineoides* (Meyer 1956) n. comb.; Krutzsch, p. 15 (without figure).

1980 *Graminidites gramineoides* (Meyer 1956) Krutzsch 1970; Thiele-Pfeiffer, p. 120, pl. 7, figs 12, 13 (Germany, Oder/Wackersdorf, Miocene).

Size. 25–30 µm, $\bar{x} = 28$ µm (n = 3)

Description. Monoporate pollen grain in circular outline. Pore circular, nexine around it thickened, forming a costa. Surface perforate sculpture.

Stratigraphic occurrence. From Upper Oligocene to Pliocene/Pleistocene in central Europe (Krutzsch 1970).

Occurrence in Shanwang. Only several specimens have been found in the profile.

Botanical affinity. Poaceae (Gramineae) after Krutzsch (1970). Since the recent Gramineae have the similar pollen forms, it is impossible to allocate this fossil grain into an extant genus.

(24) ***Graminidites micropunctatus*** Krutzsch 1970

Pl. 9, fig. 11a, b

1970 *Graminidites micropunctatus* n. sp.; Krutzsch, p. 56, 57, pl. 4, figs 1–8 (Germany, Tanndorf-Seidewitz, Lower Miocene).

1996 *Graminidites micropunctatus* Krutzsch 1970; Ashraf & Mosbrugger, p. 55, pl. 8, fig. 24 (Germany, Lower Rhine Bay, Pliocene).

Size. 25 µm (n = 1)

Description. Monoporate pollen grain in circular outline. Pore circular, nexine around it thickened, forming a costa. Surface delicate perforate sculpture. For more detailed description see Krutzsch (1970).

Stratigraphic occurrence. Miocene and Pliocene of Germany.

Occurrence in Shanwang. Only a few specimens have been found in the middle part of the profile.

Botanical affinity. Poaceae (Gramineae) after Krutzsch (1970).

(25) ***Graminidites pseudogramineus*** Krutzsch 1970

Pl. 9, fig. 10a, b

1970 *Graminidites pseudogramineus* n. sp.; Krutzsch, p. 52, pl. 1, figs 6–11 (Germany, Oberzella/Werra, Pliocene; Kaltensundheim/Rhoen, Pliocene-Pleistocene).

1989 *Graminidites pseudogramineus* Krutzsch 1970; Guan et al., p. 83, pl. 25, figs 26–29 (China, Region around Bohai Sea, Miocene to Pleistocene).

Size. 50 µm (n = 1)

Description. Monoporate pollen grain in circular outline. Pore circular, nexine around it thickened, forming a costa. Surface granulate sculpture. For more detailed description see Krutzsch (1970).

Stratigraphic occurrence. Few localities from Pliocene–Pleistocene in central Europe (Krutzsch 1970). From Miocene to Pleistocene in several localities in China (cf. Song et al. 1999).

Occurrence in Shanwang. Only several pollen grains have been found in lower part of the profile.

Botanical affinity. Probably Poaceae (Gramineae) after Krutzsch (1970).

Triporate pollen grains

Genus ***Caryapollenites*** Raatz 1937 ex Potonié 1960 emend. Krutzsch 1961

Type. *Caryapollenites simplex* (Potonié 1931) Raatz 1937

(26) ***Caryapollenites simplex*** (Potonié 1931) Raatz 1937 ex Potonié 1960

Pl. 10, figs 16, 17

1931d *Pollenites simplex* n. sp.; Potonié, p. 3, fig. 4 (Germany, Ville, Beisselsmine, Rhine brown coal, Miocene).

1937 *Carya-pollenites simplex* Potonié 1931; Raatz, p. 19, pl. 1, fig. 6 (Germany, Upper Lusatia, Babina mine – since 1945 Poland, Miocene).

1953 *Subtriporopollenites simplex* (Potonié & Venitz 1934) n. comb.; Thomson & Pflug, p. 86, pl. 9, figs 64–73 (Germany, different source localities, from Middle Oligocene to Lower Miocene, and from Middle to Upper Pliocene).

1960 *Caryapollenities simplex* Raatz 1937; Potonié, p. 123, pl. 7, figs 162, 163 (Germany, Upper Lusatia, Miocene).

1978 *Caryapollenites simplex* (Potonié 1931) Raatz 1937; IPEDPMPI-NIGPAS, p. 103, pl. 33, figs 18, 19 (China, Coastal region of Bohai Sea, Early Tertiary).

1980 *Caryapollenites simplex* (Potonié 1931) Raatz 1937 ex Potonié 1960; Thiele-Pfeiffer, p. 126, 127, pl. 8, fig. 7 (Germany, Oder/Wackersdorf, Miocene).

1984 *Caryapollenites simplex* (Potonié 1931) Raatz 1937 ex Potonié 1960; Mohr, p. 67, 68, pl. 9, figs 8.1, 8.2 (Germany, North Rhine Bay, Frechen, Fortuna Garsdorf , Miocene to Pliocene).

1994 *Caryapollenites simplex* (Potonié 1931) Raatz 1937; Ziembińska-Tworzydło et al., p. 35, pl. 8, figs 16, 17 (Poland, Neogene).

1996 *Caryapollenites simplex* (Potonié 1931) Raatz 1937 ex Potonié 1960; Ashraf & Mosbrugger, p. 66, pl. 9, fig. 23; pl. 10, fig. 1 (Germany, Lower Rhine Bay, Neogene).

Size. 36 µm (n = 1)

Description. Triporate pollen grains in circular or round-triangular outline in polar view. Pores situated regularly in the sub-equatorial plane. Exine tectate, microechinate.

Stratigraphic occurrence. From Eocene, frequent from Oligocene to Pliocene in central Europe (Krutzsch 1957); through the Tertiary in China, mainly in the Late Tertiary (Song et al. 1999).

Occurrence in Shanwang. Abundant throughout the entire profile.

Botanical affinity. Juglandaceae, *Carya* Nutt. (Thomson & Pflug 1953).

Genus ***Engelhardioidites*** Potonié, Thomson & Thiergart 1950 ex Potonié 1960

Type. *Engelhardioidites microcoryphaeus* (Potonié 1931) Potonié, Thomson & Thiergart 1950

(27) ***Engelhardioidites microcoryphaeus*** (Potonié 1931) Potonié 1960

Pl. 9, figs 12, 15

1931b *Pollenites microcoryphaeus* n. sp.; Potonié, p. 332, pl. 2, fig. 13 (Germany, Miocene).

1953 *Triatriopollenites coryphaeus* ssp. *microcoryphaeus* (Potonié 1931) n. comb.; Thomson & Pflug, p. 81, pl. 8, figs 40, 42–45 (Germany, different source localities, from Lower Eocene to Lower Miocene).
1960 *Engelhardioidites microcoryphaeus* (Potonié 1931) Potonié, Thomson & Thiergart 1950 ex Potonié; Potonié, p. 118, pl. 7, figs 148, 149 (Germany, Rhine brown coal, Micoene; Senftenberg, Lower Miocene).
1978 *Engelhardioidites microcoryphaeus* (Potonié 1931) Potonié, Thomson & Thiergart 1950 ex Potonié 1960; IPEDPMPI-NIGPAS, p. 104, pl. 34, figs 21, 22 (China, Region around Bohai Sea, Early Tertiary).
1993 *Engelhardioidites microcoryphaeus* (Potonié 1931) Potonié 1960; Kohlman-Adamska, p. 131, pl. 18, fig. 5 (North-western Poland, Lower to Middle Miocene).

Size. 19–24 μm, $\overline{x} = 21$ μm (n = 4)

Description. Small triporate pollen grain in convex triangular outline in polar view. Pore regularly distributed in equatorial plane. Endexine around the pore absent, forming a poorly seen atrium. Exine thin, tectate, granulate. Exine often folded at the centre.

Stratigraphic occurrence. From Lower Eocene to Lower Miocene in Germany (Thomson & Pflug 1953); Lower to Middle Miocene in Poland (Kohlman-Adamska 1993); Upper Eocene to Oligocene in several localities in China (cf. Song et al. 1999).

Occurrence in Shanwang. Sporadic through the entire profile.

Botanical affinity. Juglandaceae, *Engelhardia* Leschen. ex Bl. (Thomson & Pflug 1953).

Genus ***Momipites*** Wodehouse 1933

Type. *Momipites coryloides* Wodehouse 1933

(28) ***Momipites punctatus*** (Potonié 1931) Nagy 1969

Pl. 9, figs 13a, b, 14

1931b *Pollenites coryphaeus punctatus* n. f.; Potonié, p. 329, pl. 2, fig. 7 (Germany, Lower Lusatia, Babina II mine – since 1945 Poland, Miocene).
1950 *Engelhardioipollenites* (al. *Pollenites*) *punctatus* (al. *coryphaeus punctatus*); Potonié, Thomson & Thiergart, p. 51, pl. B, fig. 7 (Germany, North Rhine Bay, Liblar, Miocene).
1953 *Triatriopollenites coryphaeus* (Potonié 1931) n. comb. ssp. *punctatus* (Potonié 1931) n. comb.; Thomson & Pflug, p. 80, pl. 8, figs 15–37 (Germany, different source localities, Miocene).
1960 *Engelhardioipollenites* (al. *Pollenites*) *punctatus* (al. *coryphaeus punctatus* Potonié 1931) Potonié 1951; Potonié, p. 117, pl. 7, fig. 147 (Germany, Upper Lusatia, Muskauer Bogens, Babina II mine – since 1945 Poland, Miocene).
1969 *Momipites punctatus* (Potonié 1931) n. comb.; Nagy, p. 246 (478), pl. 54, figs 9, 10 (Hungary, Mecsek Mountains, Miocene).
1980 *Momipites punctatus* (Potonié 1931) Nagy 1969; Thiele-Pfeiffer, p. 125, 126, pl. 8, figs 5, 6 (Germany, Oder/Wackersdorf, Miocene).
1984 *Momipites punctatus* (Potonié 1931) Nagy 1969; Mohr, p. 67, pl. 9, fig. 7 (Germany, North Rhine Bay, Frechen, Fortuna Garsdorf, Miocene and Pliocene).
1994 *Engelhardioipollenites punctatus* (Potonié 1931) Potonié 1951 ex Potonié 1960; Ziembińska-Tworzydło et al., p. 36, pl. 8, fig. 20 (Poland, Neogene).
1996 *Momipites punctatus* (Potonié 1931) Nagy 1969; Ashraf & Mosbrugger, p. 60, pl. 9, figs 5–7 (Germany, Lower Rhine Bay, Neogene).

Size. 25–32 μm, $\overline{x} = 28$ μm (n = 4)

Description. Triporate pollen grain in rigid convex-triangular outline in polar view. Pore regularly distributed in equatorial plane. Endexine around the pore absent, forming wide atrium. Exine tectate, surface with microechinate sculpture.

Stratigraphic occurrence. From Eocene to Pliocene in Europe (cf. Thiele-Pfeiffer 1980).

Occurrence in Shanwang. Sporadic through the entire profile.

Botanical affinity. Juglandaceae, *Engelhardia* Leschen. ex Bl. (Thiele-Pfeiffer 1980).

Genus ***Triatriopollenites*** Pflug in Thomson & Pflug 1953

Type. *Triatriopollenites rurensis* Pflug & Thomson in Thomson & Pflug 1953

(29) ***Triatriopollenites bituitus*** (Potonié 1931) Thomson & Pflug 1953

Pl. 10, figs 6, 7

1931b *Pollenites bituitus* n. sp.; Potonié, p. 332, pl. 2, fig. 17 (Germany, Lusatia, Miocene).
1953 *Triatriopollenites bituitus* (Potonié 1931) n. comb.; Thomson & Pflug, p. 79, pl. 7, figs 116–134 (Germany, different source localities, from Eocene to Miocene).
1980 *Triatriopollenites bituitus* (Potonié 1931) Thomson & Pflug 1953; Thiele-Pfeiffer, p. 125, pl. 8, figs 2, 3 (Germany, Oder/Wackersdorf, Miocene).
1984 *Triatriopollenites bituitus* (Potonié 1931) Thomson & Pflug 1953; Mohr, p. 66, pl. 9, figs 5.1, 5.2 (Germany, North Rhine Bay, Frechen, Fortuna Garsdorf, from Miocene to Pliocene).

1994 *Municipites bituitus* (Potonié 1931) Nagy 1969; Ziembińska-Tworzydło et al., p. 36, pl. 8, figs 22, 23 (Poland, Negene).
1996 *Triatriopollenties bituitus* (Potonié 1931) Thomson & Pflug 1953; Ashraf & Mosbrugger, p. 64, pl. 9, figs 17–20 (Germany, Lower Rhine Bay, Neogene).

Size. 25–32 µm, $\overline{x} = 28$ µm (n = 5)

Description. Triporate pollen grain in rounded-triangular outline in polar view. Pores situated at the corners of the triangle in the equatorial plane. Endexine around the pore absent, forming clearly seen wide atrium with granulations. Ectexine around the pore slightly thickened. Exine tectate, finely granulate.

Stratigraphic occurrence. From Eocene probably to Pliocene (Thomson & Pflug 1953).

Occurrence in Shanwang. Frequent but not numerous throuth the profile.

Botanical affinity. Myricaceae, *Myrica* L. (Thiele-Pfeiffer 1980).

Genus *Triporopollenites* Pflug & Thomson in Thomson & Pflug 1953

Type. *Triporopollenites coryloides* Pflug 1953

(30) *Triporopollenites rhenanus* (Thomson in Potonié, Thomson & Thiergart 1950) Thomson in Thomson & Pflug 1953

Pl. 10, fig. 4

1950 *Ostrya*?-*Poll. granifer rhenanus* n. sp.; Thomson in Potonié, Thomson & Thiergart, p. 52, pl. B, figs 9, 10 (Germany, Brown coal from Fortuna, Rhine, Miocene).
1953 *Triporopollenites rhenanus* n. comb.; Thomson in Thomson & Pflug, p. 84, pl. 8, figs (?) 150–152 (Germany, Messel, Eocene; Brown coal from Rhine, Miocene).
1980 *Triporopollenites rhenanus* (Thomson in Potonié, Thomson & Thiergart 1950) Thomson & Pflug 1953; Thiele-Pfeiffer, p. 128, pl. 8, fig. 14 (Germany, Oder/Wackersdorf, Miocene).
1994 *Ostryoipollenites rhenanus* (Thomspon 1950) Potonié 1951 ex Potonié 1960; Ziembińska-Tworzydło et al., p. 36, pl. 9, fig. 2 (Poland, Neogene).

Size. 19–25 µm, $\overline{x} = 23$ µm (n = 3)

Description. Triporate pollen grain in rounded-triangular outline in polar view. Pores situated at the corners of the triangle in the equatorial plane. Nexine around the pore absent, forming atrium. Exine tectate, granulate. Similar to 3-porate *Carpinipites carpinoides* except for its smaller size.

Stratigraphic occurrence. Uncertain in Eocene, certainly in Miocene and Pliocene in Europe (cf. Thiele-Pfeiffer 1980).

Occurrence in Shanwang. Sporadic.

Botanical affinity. Betulaceae, *Ostrya* Scop. (Thomson & Pflug 1953), or *Carpinus* L. (cf. Thiele-Pfeiffer 1980). The pollen grains of these two genera are difficult to distinguish.

Genus *Trivestibulopollenites* Pflug in Thomson & Pflug 1953

Type. *Trivestibulopollenites betuloides* Pflug in Thomson & Pflug 1953

(31) *Trivestibulopollenites betuloides* Pflug in Thomson & Pflug 1953

Pl. 10, figs 3, 8a, b

1953 *Trivestibulopollenites betuloides* n. sp. Pflug in Thomson & Pflug, p. 85, pl. 9, figs 25–34 (Germany, different source localities, from Miocene to Pliocene).
1980 *Trivestibulopollenites betuloides* Pflug 1953; Thiele-Pfeiffer, p. 128, pl. 8, fig. 13 (Germany, Oder/Wackersdorf, Miocene).
1984 *Trivestibulopollenites betuloides* Pflug 1953; Mohr, p. 69, pl. 9, fig. 13 (Germany, North Rhine Bay, Frechen, Fortuna Garsdorf, Upper Miocene to Lower Pliocene).
1985 *Betulaepollenites lenghuensis* Song & Zhu n. sp.; Zhu et al., p. 137, pl. 36, figs 31–34 (Northwest China, Qaidamu Basin, Miocene).
1989 *Betulaeopollenites plicoides* (Zakl.) Sung & Tsao 1976; Guan et al., p. 67, pl. 20, figs 20–23, 25, 26 (China, Region around Bohai Sea, Miocene to Pliocene).
1994 *Betulaepollenites betuloides* (Pflug 1953) Nagy 1969; Ziembińska-Tworzydło et al., p. 35, pl. 8, fig. 15 (Poland, Neogene).
1996 *Trivestibulopollenites betuloides* Pflug in Thomson & Pflug 1953; Ashraf & Mosbrugger, p. 62, pl. 9, figs 13–15 (Germany, Lower Rhine Bay, Neogene).

Size. 18–21 µm, $\overline{x} = 20$ µm (n = 3)

Description. Triporate pollen grains in convex-triangular outline in polar view. Pores protruding, situated at corners of the triangle in the equatorial plane, with characteristic vestibula. Exine tectate, psilate.

Stratigraphic occurrence. From Middle Oligocene to Miocene, frequent in Pliocene (cf. Thiele-Pfeiffer 1980).

Occurrence in Shanwang. Frequent but not numerous in the whole profile.

B o t a n i c a l   a f f i n i t y. Betulaceae, *Betula* L. (Thomson & Pflug 1953).

Polyporate pollen grains

Genus ***Alnipollenites*** Potonié 1931

T y p e. *Alnipollenites verus* Potonié 1931

(32) ***Alnipollenites verus*** Potonié 1931

Pl. 11, figs 12, 13

1931b *Pollenites verus* n. sp.; Potonié, p. 329, pl. 2, fig. 40 (Germany, Lusatia, Miocene).
1931d *Alnipollenites verus* Potonié 1931; Potonié, p. 4, fig. 18 (Germany, Tertiary).
1953 *Polyvestibulopollenites* (*Alnipollenites*) *verus* (Potonié 1931) n. comb.; Thomson & Pflug, p. 90, pl. 10, figs 62–76 (Germany, different source localities, from Eocene to Pliocene).
1978 *Alnipollenites verus* (Potonié 1931) Potonié 1960; IPEDPMPI-NIGPAS, p. 107, pl. 34, figs 39–43; pl. 35, figs 1–7 (China, Coastal region of Bohai Sea, Early Tertiary).
1980 *Polyvestibulopollenites verus* (Potonié 1931) Thomson & Pflug 1953; Thiele-Pfeiffer, p. 127, pl. 8, figs 11, 12 (Germany, Oder/Wackersdorf, Miocene).
1989 *Alnipollenites verus* (Potonié 1931) Potonié 1960; Guan et al., p. 65, pl. 19, figs 13–24 (China, Region around Bohai Sea, Miocene to Pliocene).
1994 *Alnipollenites verus* Potonié 1931 ex Potonié 1960; Ziembińska-Tworzydło et al., p. 36, pl. 9, figs 5–7 (Poland, Neogene).
1996 *Alnipollenites verus* (Potonié 1931) Potonié 1934; Ashraf & Mosbrugger, p. 72, pl. 11, figs 1–3 (Germany, Lower Rhine Bay, Neogene).

S i z e. 23–28 µm, $\bar{x} = 25$ µm (n = 6)

D e s c r i p t i o n. Pollen grains 4–5-porate, normally 5 pores, in rounded-polygonal outline in polar view. Pores with vestibula. Neighbouring pores connected by arc-like bands of endexinous thickening. Exine tectate, psilate.

S t r a t i g r a p h i c   o c c u r r e n c e. World-wide occurring from Lower Eocene, abundant from Oligocene to Pliocene (Thomson & Pflug 1953, Krutzsch 1957, Song et al. 1999).

O c c u r r e n c e   i n   S h a n w a n g. Frequent.

B o t a n i c a l   a f f i n i t y. Betulaceae, *Alnus* B. Ehrh. (Thomson & Pflug 1953).

Genus ***Carpinipites*** Srivastava 1966

T y p e. *Carpinipites ancipites* (Wodehouse 1933) Srivastava 1966

(33) ***Carpinipites carpinoides*** (Pflug in Thomson & Pflug 1953) Nagy 1985

Pl. 10, figs 1, 2

1953 *Polyporopollenites carpinoides* n. sp.; Pflug in Thomson & Pflug, p. 92, pl. 10, figs 79–83 (Germany, different source localities, Oligocene, Miocene and Pliocene).
1969 *Carpinuspollenites carpinoides* (Pflug 1953) n. comb.; Nagy, p. 226 (458), pl. 52, fig. 8 (Hungary, Mecsek, Miocene).
1978 *Carpinipites orbicularis* (Potonié) Sung & Zheng n. sp.; IPEDPMPI-NIGPAS, p. 109, pl. 36, figs 24–27 (China, Coastal region of Bohai Sea, Early Tertiary).
1980 *Carpinuspollenites carpinoides* (Pflug 1953) Nagy 1969; Thiele-Pfeiffer, p. 128, pl. 8, figs 15, 16 (Germany, Oder/Wackersdorf, Miocene).
1985 *Carpinipites carpinoides* (Pflug in Thomson & Pflug 1953) n. comb.; Nagy, p. 198, pl. 112, figs 9–14 (Hungary, Miocene).
1985 *Carpinipites subtriangulus* (Stanley) Guan n. comb.; Song et al., p. 98, pl. 31, figs 10–12 (China, Longjing Structural Area in the Shelf Basin of the East China Sea Region, Pliocene to Pleistocene).
1985 *Carpinipites orbicularis* (Potonié) Song & Zheng; Song et al., p. 98, pl. 31, fig. 18 (China, Longjing Structural Area in the Shelf Basin of the East China Sea Region, Pliocene to Pleistocene).
1994 *Carpinipites carpinoides* (Pflug 1953) Nagy 1985; Ziembińska-Tworzydło et al., p. 36, pl. 9, figs 8, 9 (Poland, Neogene).

S i z e. 27–35 µm, $\bar{x} = 30$ µm (n = 6)

D e s c r i p t i o n. Pollen grains 3–5-porate, in rounded-triangular or circular outline in polar view. Pores situated at the corners of the polygon in the equatorial plane. Nexine around the pore absent, forming a poorly seen atrium. Exine tectate, granulate.

S t r a t i g r a p h i c   o c c u r r e n c e. From Oligocene to Pliocene in central Europe (Thomson & Pflug 1953). Several localities in China during Tertiary (cf. Song et al. 1999).

O c c u r r e n c e   i n   S h a n w a n g. Abundant along the whole profile.

B o t a n i c a l   a f f i n i t y. Betulaceae, *Carpinus* L. (Nagy 1969).

Genus ***Celtipollenites*** Nagy 1969

T y p e. *Celtipollenites komloensis* Nagy 1969

(34) ***Celtipollenites komloensis*** Nagy 1969

Pl. 5, fig. 8a, b

1969 *Celtipollenites komloensis* n. gen. n. sp.; Nagy, p. 224 (456), pl. 43, figs 3, 7 (Hungary, Mescek mountain, Miocene).

1978 *Celtispollenites dongyingensis* Ke & Shi n. sp.; IPEDPMPI-NIGPAS, p. 114, pl. 38, figs 7–11 (China, Coastal region of Bohai Sea, Early Tertiary).
1989 *Celtispollenites dongyingensis* Ke & Shi 1978; Guan et al., p. 106, pl. 38, figs 20, 21 (China, Region around Bohai Sea, Miocene to Pliocene).

Size. 32 µm (n = 1)

Description. Pollen grains 5–6-porate, in circular outline in polar view. Pores with scabrous membrane, distributed inexactly in equatorial plane, surrounded by thin annuli. Exine tectate, granulate.

Stratigraphic occurrence. *Celtis*-form pollen occurs from younger Palaeogene in central and eastern Europe, from the Neogene in several localities in eastern Europe. From Eocene to Pliocene in several areas in China.

Occurrence in Shanwang. Rare but distributed throughout the entire profile.

Botanical affinity. Ulmaceae, *Celtis* L., probably *C. occidentalis* L. (Nagy 1969).

(35) ***Celtipollenites intrastructurus*** (Krutzsch & Vanhoorne 1977) Thiele-Pfeiffer 1980

Pl. 5, figs 5, 7a, b, 9, 10a, b

1977 *Subtriporopollenites intrastructurus* n. fsp.; Krutzsch & Vanhoorne, p. 58, pl. 23, figs 8–11, 15–19 (Belgium, Epinois, Lower Eocene).
1978 *Celtispollenites minor* Ke & Shi n. sp.; IPEDPMPI-NIGPAS, p. 115, pl. 38, figs 1–6 (China, Coastal region of Bohai, Early Tertiary).
1980 *Celtipollenites intrastructurus* (Krutzsch & Vanhoorne 1977) n. comb.; Thiele-Pfeiffer, p. 130, 131, pl. 8, figs 32–34 (Germany, Oder/Wackersdorf, Miocene).
1981 *Celtispollenites triporatus* Sun & Li n. sp.; Sun et al., p. 44, pl. 16, figs 72–74 (China, North continental shelf of South China Sea, Palaeocene).
1984 *Celtipollenites intrastructurus* (Krutzsch & Vanhoorne 1977) Thiele-Pfeiffer 1980; Mohr, p. 71, pl. 10, fig. 5 (Germany, Frechen, Miocene).
1989 *Celtispollenites minor* Ke & Shi 1978; Guan et al., p. 107, pl. 38, figs 10–12 (China, Bohai Sea region, Miocene to Pliocene).
1994 *Celtipollenites intrastructurus* (Krutzsch & Vanhoorne 1977) Thiele-Pfeiffer 1980; Ziembińska-Tworzydło et al., p. 36, pl.9, fig. 10 (Poland, Neogene).
1996 *Celtipollenites intrastructurus* (Krutzsch & Vanhoorne 1977) Thiele-Pfeiffer 1980; Ashraf & Mosbrugger, p. 35, without figure (Germany, Lower Rhine Bay, Neogene).

Size. 23–34 µm, $\bar{x} = 28$ µm (n = 5)

Description. Pollen grains triporate, in circular outline in polar view. Pores surrounded by narrow annuli, distributed in equatorial plane. Exine tectate, finely granulate.

Stratigraphic occurrence. Lower Eocene in Epinois, Belgium (Krutzsch & Vanhoorne 1977); Miocene in Southern Germany (Thiele-Pfeiffer 1980, Mohr 1984). From several localities in China during the Tertiary (cf. Song et al. 1999).

Occurrence in Shanwang. Frequently occurs in the middle and lower parts of the profile, but fewer in the upper part of the profile.

Botanical affinity. Ulmaceae, *Celtis* L. It is especially similar to pollen grains of, *C. formosana* Hayata and *C. occidentalis* L. (Thiele-Pfeiffer 1980).

Genus ***Chenopodipollis*** Krutzsch 1966

Type. *Chenopodipollis multiplex* (Weyland & Pflug 1957) Krutzsch 1966

(36) ***Chenopodipollis maximus*** (Nagy 1969) **comb. nov.**

Pl. 11, fig. 18a, b

1969 *Chenopodipollenites maximus* n. sp.; Nagy, p. 215 (447), pl. 1, figs 5, 6 (Hungary, Mecsek Mountain, Miocene).
1985 *Chenopodipollenites maximus* Nagy 1969; Nagy, p. 189, pl. 108, figs 5, 6 (Hungary, Miocene).
1985 *Chenopodipollenites maximus* Nagy 1969; Zhu et al., p. 146, pl. 39, figs 11, 12 (Northwest China, Qaidamu Basin, Oligocene to Miocene).

Size. 43 µm (n = 1)

Description. Polypantoporate pollen grain distorted in broadly elliptic outline during the course of fossilization. Different from the *Chenopodipollis multiplex* in its larger size, thicker exine and much wavier outline.

Stratigraphic occurrence. Middle Miocene, Badenian stage, Hungary (Nagy 1969), and from Oligocene to Miocene in Northwest China (Zhu et al. 1985).

Occurrence in Shanwang. Only several specimens have been encountered in lower part of the profile.

Botanical affinity. Chenopodiaceae (Nagy 1969).

(37) ***Chenopodipollis multiplex*** (Weyland & Pflug 1957) Krutzsch 1966

Pl. 11, figs 15, 16a, b, 17; Pl. 12, fig. 2a, b

1957 *Periporo-pollenites multiplex* n. sp.; Weyland & Pflug, p. 103, pl. 22, figs 18, 19 (North Greece, brown coal from Ptolemais, Pliocene).
1966 *Chenopodipollis* (al. *Periporopollenites*) *multiplex* (Weyland & Pflug 1957) n. comb.; Krutzsch, p. 35, pl. VII, figs 22–25 (Germany, Torgau Axien drill, Oligocene to Miocene; Stradow drill, Miocene).
1980 *Chenopodipollis multiplex* (Weyland & Pflug 1957) Krutzsch 1966; Thiele-Pfeiffer, p. 139, 140, pl. 10, figs 4, 5 (Germany, Oder/Wackersdorf, Miocene).
1984 *Chenopodipollis multiplex* (Weyland & Pflug 1957) Krutzsch 1966; Mohr, p. 73, pl. 10, figs 7, 8 (Germany, North Rhine Bay, Frechen, Fortuna Garsdorf, Miocene to Pliocene).
1985 *Chenopodipollis multiplex* (Weyland & Pflug 1957) Krutzsch 1966; Zhu et al., p. 147, pl. 39, figs 20–22 (Northwest China, Qaidamu Basin, Oligocene to Pliocene).
1994 *Chenopodipollis multiplex* (Weyland & Pflug 1957) Krutzsch 1966; Ziembińska-Tworzydło et al., p. 36, pl. 9, fig. 14 (Poland, Neogene).
1996 *Chenopodipollis multiplex* (Weyland & Pflug 1957) Krutzsch 1966; Ashraf & Mosbrugger, p. 75, pl. 11, figs 8, 9 (Germany, Lower Rhine Bay, Neogene).

Size. 15–26 µm, $\bar{x}$ = 23 µm (n = 3)

Description. Polypantoporate pollen grains in circular outline. Exine tectate, tectum psilate. Columellae densely distributed under the tectum. For more detailed description see Krutzsch (1966).

Stratigraphic occurrence. From Middle Oligocene to Pliocene in central and eastern Europe (Thiele-Pfeiffer 1980); from Oligocene to Pleistocene in several localities in China.

Occurrence in Shanwang. Sporadic occurrences through the whole profile. Abruptly increasing in the middle part of the profile.

Botanical affinity. Chenopodiaceae/Amaranthaceae (Thiele-Pfeiffer 1980).

Genus ***Juglandipollis*** Kohlman-Adamska in Ziembińska-Tworzydło et al. 1994

Type. *Juglandipollis juglandoides* Kohlman-Adamska in Ziembińska-Tworzydło et al. 1994

(38) ***Juglandipollis juglandoides*** Kohlman-Adamska in Ziembińska-Tworzydło et al. 1994

Pl. 12, figs 11, 13

1989 *Juglanspollenites rotundus* Ke & Shi 1978; Guan et al., p. 86, pl. 30, figs 5–8 (China, Region around Bohai Sea, Miocene to Pliocene).
1994 *Juglandipollis juglandoides* Kohlman-Adamska n. sp.; Ziembińska-Tworzydło et al., p. 18, pl. 9, figs 18, 19 (Poland, Neogene).

Size. 33–44 µm, $\bar{x}$ = 38 µm (n = 4)

Description. Polyporate pollen grains in circular outline in polar view. Pores circular, distributed in the equator area, and on one hemisphere. Exine tectate, tectum surface microechinate. Often with secondary fold.

Stratigraphic occurrence. Miocene to Pliocene (Ziembińska-Tworzydło et al. 1994).

Occurrence in Shanwang. Abundant in the whole profile.

Botanical affinity. Juglandaceae, *Juglans* L. (Ziembińska-Tworzydło et al. 1994).

Genus ***Periporopollenites*** Pflug & Thomson in Thomson & Pflug 1953 emend. Krutzsch 1966

Type. *Periporopollenites stigmosus* (Potonié 1931) Pflug & Thomson in Thomson & Pflug 1953 ex Jansonius & Hills 1976

(39) ***Periporopollenites formosanaeformis*** (Nagy 1969) **comb. nov.**

Pl. 12, figs 5a, b, 6

1969 *Liquidambarpollenites formosanaeformis* n. sp.; Nagy, p. 172 (404), pl. 41, figs 9, 14 (Hungary, Mecsek mountain, Miocene).
1978 *Liquidambarpollenites stigmosus* (Potonié 1931) Raatz 1937; IPEDPMPI-NIGPAS, p. 122, pl. 41, figs 15–18, 20, 21 (China, Coastal region of Bohai Sea, Upper Eocene to Oligocene).
1985 *Liquidambarpollenites formosanaeformis* Nagy 1969; Nagy, p. 158, pl. 40, figs 18–20 (Hungary, Lower Badenian, Upper Pannonian).
1989 *Liquidambarpollenites stigmosus* (Potonié 1931) Raatz 1937; Guan et al., pl. 19, figs 8–11 (China, Region around Bohai Sea, Miocene to Pliocene).

Size. 32–44 µm, $\bar{x}$ = 39 µm (n = 4)

Description. Polypantoporate pollen grains in circular outline. Pores round, smooth margins, covered with granulate membranes. Exine semitectate, reticulate.

Stratigraphic occurrence. From Oligocene to Pliocene in central Europe (Krutzsch 1966); several localities from China during Tertiary (cf. Song et al. 1999).

Occurrence in Shanwang. Mostly abundant throughout the entire profile.

Botanical affinity. Altingiaceae, *Liqui-*

dambar formosana Hence (Nagy 1969), or *Altingia* Nor. (Song et al. 1999).

(40) ***Periporopollenites orientaliformis*** (Nagy 1969) **comb. nov.**

Pl. 12, figs 1a, b, 4

1969 *Liquidambarpollenites orientaliformis* n. sp.; Nagy, p. 171 (403), pl. 42, figs 1, 2 (Hungary, Mecsek Mountain, Miocene).
1978 *Liquidambarpollenites orientalisformis* Ke & Shi n. sp.; IPEDPMPI-NIGPAS, p. 121, pl. 43, figs 23–26 (China, Coastal region of Bohai Sea, Early Tertiary).
1985 *Liquidambarpollenites orientaliformis* Nagy 1969; Nagy, p. 158, pl. 90, figs 21, 22; pl. 91, fig. 1 (Hungary, Lower Badenian and Upper Pannonian).
1985 *Liquidambarpollenites orientaliformis* Nagy 1969; Song et al., p. 119, pl. 39, figs 22–24, 26, 28 (China, Longjing Structural Area in the Shelf Basin of the East China Sea Region, Upper Eocene to Pleistocene).

Size. 40–50 μm, $\bar{x} = 45$ μm (n = 4)

Description. Polypantoporate pollen grains in circular outline. Pores strongly elongated, smooth margins, covered with coarsely granulate membranes. Exine semitectate, coarsely foveolate-reticulate.

Stratigraphic occurrence. Miocene in Hungary (Nagy 1969); several localities in China during the Tertiary (cf. Song et al. 1999).

Occurrence in Shanwang. Mostly abundant throughout the entire profile.

Botanical affinity. Altingiaceae, *Liquidambar orientalis* Mill. (Nagy 1969).

(41) ***Periporopollenites styracifluaeformis*** (Nagy 1969) **comb. nov.**

Pl. 12, figs 7, 8

1969 *Liquidambarpollenites styracifluaeformis* n. sp.; Nagy, p. 172 (404), pl. 41, figs 13, 20 (Hungary, Mecsek, Miocene).
1978 *Liquidambarpollenites styracifluaformis* Ke & Shi n. sp.; IPEDPMPI-NIGPAS, p. 123, pl. 41, figs 12–14 (China, Coastal region of Bohai Sea, Upper Eocene to Oligocene).
1985 *Liquidambarpollenites styracifluaeformis* Nagy 1969; Nagy, p. 158–160, pl. 91, figs 2–4 (Hungary, Miocene).
1989 *Liquidambarpollenites styracifluaeformis* Nagy 1969; Guan et al., pl. 19, figs 6, 7 (China, Region around Bohai Sea, Miocene to Pliocene).

Size. 34–41 μm, $\bar{x} = 38$ μm (n = 4)

Description. Polypantoporate pollen grains in circular outline. Pores with irregular margins, with some finely small cracks at the rims, covered with granulate membranes. Exine semitectate, reticulate.

Stratigraphic occurrence. Miocene in Hungary (Nagy 1969); several localities in China during Tertiary (cf. Song et al. 1999).

Occurrence in Shanwang. Frequent but not in numerous.

Botanical affinity. Altingiaceae, *Liquidambar* L., probably *L. styraciflua* L. (Nagy 1969).

Genus ***Persicarioipollis*** Krutzsch 1962

Type. *Persicarioipollis meuseli* Krutzsch 1962

(42) ***Persicarioipollis franconicus*** Krutzsch 1962

Pl. 12, fig. 10a, b

1962 *Persicarioipollis franconicus* n. fsp.; Krutzsch, p. 284, fig. 12h, pl. 10, figs 2–8 (South France; Germany, Wetterau, Freigericht, Pliocene).
1985 *Persicarioipollis franconicus* Krutzsch 1962; Song et al., p. 134, pl. 47, fig. 27 (China, Longjing Structural Area in the Shelf Basin of the East China Sea Region, Pliocene to Pleistocene).

Size. 50 μm (n = 1)

Description. Pantocolpate pollen grains in circular outline. Coarsely reticulate sculpture forming the network pattern on the surface. The width of the lumina much wider than the breadth of muri. Bacula standing in double lines. For more detailed description see Krutzsch (1962).

Stratigraphic occurrence. From Miocene to Pliocene in Europe (Krutzsch 1962, 1966); from Pliocene to Pleistocene in the East China Sea region (cf. Song et al. 1985, 1999).

Occurrence in Shanwang. Very rare.

Botanical affinity. Polygonaceae, *Polygonum* L. (cf. Thiele-Pfeiffer 1980).

(43) ***Persicarioipollis welzowense*** Krutzsch 1962

Pl. 12, fig. 12a–c

1962 *Persicarioipollis welzowense* n. fsp.; Krutzsch, p. 284, 304, pl. 9, figs 6–12 (Germany, Lusatia, Lower Miocene).
1980 *Persicarioipollis welzowense* Krutzsch 1962; Thiele-Pfeiffer, p. 141, pl. 10, figs 12–14 (Germany, Oder/Wackersdorf, Miocene).

1984 *Persicarioipollis welzowense* Krutzsch 1962; Mohr, p. 75, pl. 2, figs 8.1, 8.2 (Germany, Frechen, Fortuna Garsdorf, Upper Miocene).
1986 *Persicarioipollis welzowense* Krutzsch 1962; Liu, pl. 4, figs 45–47, 50–52 (China, Shandong, Shanwang, Yaoshan Formation, Miocene).
1989 *Persicarioipollis welzowense* Krutzsch 1962; Guan et al., p. 98, pl. 34, figs 14–18 (China, Region around Bohai Sea, Miocene to Pleistocene).
1996 *Persicarioipollis welzowense* Krutzsch 1962; Ashraf & Mosbrugger, p. 77, pl. 11, figs 15, 16 (Germany, Lower Rhine Bay, Neogene).

Size. 30–40 µm, $\bar{x}$ = 35 µm (n = 2)

Description. Pantocolpate pollen grains in circular outline. Reticulate sculpture forming the network pattern on the surface. Difference from *Persicarioipollis franconicus* Krutzsch 1962 in its surface network pattern. For more detailed description see Krutzsch (1962).

Stratigraphic occurrence. From Miocene to Pleistocene in Europe (Krutzsch 1962, 1966); from Oligocene to Pleistocene in several localities in China (cf. Song et al. 1999).

Occurrence in Shanwang. Very rare.

Botanical affinity. Polygonaceae, *Polygonum* L. (cf. Thiele-Pfeiffer 1980).

Genus ***Pterocaryapollenites*** Thiergart 1937 ex Potonié 1960

Type. *Pterocaryapollenites stellatus* (Potonié 1931) Thiergart 1937

(44) ***Pterocaryapollenites stellatus*** (Potonié 1931) Thiergart 1937

Pl. 11, figs 11a, b, 14a, b

1931a *Pollenites stellatus* n. sp.; Potonié, p. 28, pl. 2, fig. V47b (Germany, Ville, Beissels mine, Brown coal from Rhine, Miocene).
1937 *Pterocarya-pollenites stellatus* (Potonié 1931); Thiergart, p. 311, pl. 24, fig. 19 (Germany, Lower Lusatia, Senftenberg Marga mine, Miocene).
1978 *Pterocaryapollenites stellatus* (Potonié 1931) Raatz 1937; IPEDPMPI-NIGPAS, p. 106, pl. 33, figs 20–24 (China, Coastal region of Bohai Sea, Early Tertiary).
1980 *Pterocaryapollenites stellatus* (Potonié 1931) Thiergart 1937; Thiele-Pfeiffer, p. 127, pl. 8, fig. 8 (Germany, Oder/Wackersdorf, Miocene).
1984 *Pterocaryapollenites stellatus* (Potonié 1931) Thiergart 1937; Mohr, p. 68 (Germany, North Rhine Bay, Frechen, Fortuna Garsdorf, Upper Miocene to Lower Pliocene).
1985 *Pterocaryapollenites stellatus* (Potonié 1931) Raatz 1937; Song et al., pl. 43, figs 13–15, 18–20 (China, Longjing Structural Area in the Shelf Basin of the East China Sea Region, Miocene to Pliocene).
1994 *Pterocaryapollenites stellatus* (Potonié 1931) Thiergart 1937; Ziembińska-Tworzydło et al., p. 37, pl. 10, figs 1–3 (Poland, Neogene).
1996 *Pterocaryapollenites stellatus* (Potonié 1931) Thiergart 1937; Ashraf & Mosbrugger, p. 74, pl. 11, figs 5, 6 (Germany, Lower Rhine Bay, Neogene).

Size. 21–33 µm, $\bar{x}$ = 28 µm (n = 4)

Description. Pollen grains 4–5-porate, in polygonal outline in polar view. Pores in slightly sub-equatorial position. Exine microechinate.

Stratigraphic occurrence. From Middle Eocene to Lower Pleistocene, abundant from Upper Oligocene to Upper Miocene (Thomson & Pflug 1953, Krutzsch 1957).

Occurrence in Shanwang. Frequent throughout the entire profile.

Botanical affinity. Juglandaceae, *Pterocarya* Kunth. (cf. Thiele-Pfeiffer 1980).

Genus ***Punctioratipollis*** Krutzsch 1966

Type. *Punctioratipollis ludwigi* Krutzsch 1966

(45) ***Punctioratipollis ludwigii*** Krutzsch 1966

Pl. 12, fig. 3a, b

1966 *Punctioratipollis ludwigii* n. fsp.; Krutzsch, p. 37, pl. VII, figs 31–37 (Germany, Upper Oligocene to Miocene).

Size. 24–40 µm, $\bar{x}$ = 33 µm (n = 6)

Description. Pantoporate pollen grains in circular outline. More than 20 pores all over the surface. Pores smooth margins, covered with granulate membranes. Exine tectate, psilate. Columellae densely distributed under the tectum.

Stratigraphic occurrence. From Upper Oligocene to Miocene in central Europe (Krutzsch 1966), and current Miocene material from Shanwang, China.

Occurrence in Shanwang. Sporadic.

Botanical affinity. Ranunculaceae, *Thalictrum* L., Polygonaceae, Alismataceae, or Berberidaceae (Krutzsch 1966).

Genus ***Ulmipollenites*** Wolff 1934

Type. *Ulmipollenites undulosus* Wolff 1934

Remarks. Thomson & Pflug (1953) established the Genus *Polyporopollenites* and the type species is *Polyporopollenites undulosus*.

They considered the more rounded shape of the pollen grains of *Polyporopollenites undulosus* belong to the genus *Ulmus* L., while the more angular shaped pollen grains belong to the genus *Zelkova* Spach. According to Potonié (1960 p. 131), the genus *Polyporopollenites* Thomson & Pflug 1953 was younger synonym of *Ulmipollenites* Wolff 1934. In 1969, Nagy established the genus *Zelkovaepollenites*. The present investigation adopts *Ulmipollenites undulosus* Wolff 1934 for round *Ulmus*-type pollen grains, and *Zelkovaepollenites potoniéi* Nagy 1969, *Zelkovaepollenites thiergartii* Nagy 1969 for angular *Zelkova*-type pollen grains.

(46) ***Ulmipollenites undulosus*** Wolff 1934

Pl. 11, figs 5a, b, 6, 7

1934 *Ulmi-pollenites undulosus* n. sp.; Wolff, p. 75, pl. 5, fig. 25 (Germany, Hessen, Dettingen/Main Freigericht Mine, Pliocene).
1953 *Polyporopollenites undulosus* (Wolff 1934) n. comb.; Thomson & Pflug, p. 91, pl. 10, figs 52, 53, 55 (Germany, Brown coal from Frielendorf, Miocene; Brown coal from Wallensen, Pliocene).
1969 *Ulmipollenites undulosus* Wolff 1934; Nagy, p. 222 (454), pl. 52, fig. 5 (Hungary, Mecsek, Miocene).
1980 *Polyporopollenites undulosus* (Wolff 1934) Thomson & Pflug 1953; Thiele-Pfeiffer, p. 129, pl. 8, figs 17–20 (Germany, Oder/Wackersdorf, Middle Miocene).
1984 *Polyporopollenites undulosus* (Wolff 1934) Thomson & Pflug 1953; Mohr, p. 70, 71, pl. 10, figs 2.1, 2.2 (Germany, North Rhine Bay, Frechen, Fortuna Garsdorf, from Miocene to Pliocene).
1985 *Ulmipollenites undulosus* Wolff 1934; Nagy, p. 196, pl. 111, figs 12–14 (Hungary, from Egerian to Pannonian).
1994 *Ulmipollenites undulosus* Wolff 1934; Ziembińska-Tworzydło et al., p. 37, pl. 10, fig. 7 (Poland, Neogene).

S i z e. 30–38 μm, $\bar{x} = 34$ μm (n = 4)

D e s c r i p t i o n. Pollen grains 4–5-porate, in circular outline in polar view. Exine tectate, finely rugulate. Wall slightly wavy outline, middle part of the wall between neighbouring pores slightly thin.

S t r a t i g r a p h i c occurrence. Pollen of the *Ulmipollenites* group occurs in Eocene, and is frequent from Oligocene to Pleistocene (cf. Thiele-Pfeiffer 1980).

O c c u r r e n c e in S h a n w a n g. Very abundant through the whole profile.

B o t a n i c a l affinity. Ulmaceae, *Ulmus* L. (Wolff 1934).

Genus ***Zelkovaepollenites*** Nagy 1969

T y p e. *Zelkovaepollenites potoniei* Nagy 1969

(47) ***Zelkovaepollenites potoniei*** Nagy 1969

Pl. 11, figs 1, 2

1953 *Polyporopollenites undulosus* (Wolff 1934) n. comb.; Thomson & Pflug, p. 91, pl. 10, figs 56, 57 (Germany, Brown coal from Frielendorf, Miocene; Brown coal from Wallensen , Pliocene).
1969 *Zelkovaepollenites potoniei* n. gen. n. sp.; Nagy, p. 225 (457), pl. 51, figs 17, 20 (Hungary, Miocene).
1985 *Zelkovaepollenites potoniei* Nagy 1969; Song et al., p. 149, pl. 52, figs 32–41 (China, Longjing Structural Area in the Shelf Basin of the East China Sea Region, Miocene to Pleistocene).
1985 *Zelkovaepollenites potoniei* Nagy 1969; Nagy, p. 197, pl. 112, figs 1–4 (Hungary, Miocene).
1994 *Zelkovaepollenites potoniei* Nagy 1969; Ziembińska-Tworzydło et al., p. 37, pl. 10, figs 8–10 (Poland, Neogene).

S i z e. 31–42 μm, $\bar{x} = 37$ μm (n = 4)

D e s c r i p t i o n. Pollen grains 4–5-porate, in polygonal outline in polar view. Pores situated on the angles in the equatorial plane. Exine tectate, strongly rugulate. Wall almost straight.

S t r a t i g r a p h i c occurrence. *Zelkovaepollenites* group occurring from Eocene to Pleistocene (cf. Thiele-Pfeiffer 1980).

O c c u r r e n c e in S h a n w a n g. Abundant.

B o t a n i c a l affinity. Ulmaceae, *Zelkova* Spach (Nagy 1969).

(48) ***Zelkovaepollenites thiergartii*** Nagy 1969

Pl. 11, figs 3, 4

1953 *Polyporopollenites undulosus* (Wolff 1934) n. comb.; Thomson & Pflug, p. 91, pl. 10, figs 54, 58 (Germany, Brown coal from Frielendorf, Miocene; Brown coal from Wallensen, Pliocene).
1969 *Zelkovaepollenites thiergartii* n. gen. n. sp.; Nagy, p. 225 (457), pl. 51, figs 14, 15 (Southern Hungary, Mecsek Mountains, Miocene).
1985 *Zelkovaepollenites thiergartii* Nagy 1969; Nagy, p. 197, pl. 112, figs 5–8 (Hungary, Miocene).
1989 *Zelkovaepollenites thiergartii* Nagy 1969; Guan et al., p. 109, pl. 39, figs 8, 9 (China, Region around Bohai Sea, Miocene to Pleistocene).

S i z e. 25–35 μm, $\bar{x} = 30$ μm (n = 4)

D e s c r i p t i o n. Pollen grains 4–5-porate, in polygonal outline in polar view. Pores often situated in the sub-equatorial plane. Neighbouring pores connected by weak arci-like bands. Exine tectate, finely rugulate. Wall wavy outline.

Stratigraphic occurrence. *Zelkovaepollenites* group occurring from Eocene to Pleistocene (cf. Thiele-Pfeiffer 1980).

Occurrence in Shanwang. Abundant.

Botanical affinity. Ulmaceae, *Zelkova* Spach (Nagy 1969).

(49) ***Zelkovaepollenites verrucatus*** ssp. ***minor*** (Thiele-Pfeiffer 1980) **comb. nov.**

Pl. 11, figs 8, 9, 10a, b

1980 *Polyporopollenites verrucatus* n. sp. *minor* n. ssp.; Thiele-Pfeiffer, p. 130, pl. 8, figs 28–31 (Germany, Oder/Wackersdorf, Miocene).
1996 *Polyporopollenites verrucatus* Thiele-Pfeiffer 1980 ssp. *minor*; Ashraf & Mosbrugger, p. 73, 74, without figure (Germany, Lower Rhine Bay, Neogene).

Size. 22–30 µm, $\bar{x} = 27$ µm (n = 6)

Description. Pollen grains 4–5-porate, in circular outline in polar view. Surface finely verrucate sculpture. Verrucae in nearly uniform size. Wall wavy outline.

Stratigraphic occurrence. Miocene and Pliocene (Thiele-Pfeiffer 1980).

Occurrence in Shanwang. Frequent but not numerous.

Botanical affinity. Ulmaceae, *Zelkova* Spach (Thiele-Pfeiffer 1980).

<u>Tricolpate pollen grains</u>

Genus ***Aceripollenites*** Nagy 1969

Type. *Aceripollenites reticulatus* Nagy 1969

(50) ***Aceripollenites striatus*** (Pflug 1959) Thiele-Pfeiffer 1980

Pl. 5, figs 3a, b, 6a, b

1959 *Tricolpo-pollenites striatus* n. sp.; Pflug, p. 55, pl. 16, fig. 13 (Iceland, Eocene).
1969 *Aceripollenites reticulatus* n. gen. n. sp.; Nagy, p. 181 (413), pl. 43, figs 5, 6 (Hungary, Mecsek Mountain, Miocene).
1980 *Aceripollenites striatus* n. comb.; Thiele-Pfeiffer, p. 145, 146, pl. 11, figs 22–25 (Germany, Oder/Wackersdorf, Miocene).
1985 *Aceripollenites reticulatus* Nagy 1969; Nagy, p. 166, pl. 95, figs 28–31 (Hungary, Miocene).
1985 *Aceripollenites reticulatus* Nagy 1969; Zhu et al., p. 133, pl. 43, figs 6–8 (Northwest China, Chaidamu Basin, Qinghai Province, Miocene).
1985 *Aceripollenites striatus* (Pflug 1959) Thiele-Pfeiffer 1980; Song et al., p. 92, pl. 30, figs 35–38 (China, Longjing Structural Area in the Shelf Basin of the East China Sea Region, Miocene).
1990 *Aceripollenites striatus* (Pflug 1959) Thiele-Pfeiffer 1980; Planderová, p. 77, pl. 76, figs 1–3 (Slovakia, Central Paratethys, Miocene).
1994 *Aceripollenites striatus* (Pflug 1959) Thiele-Pfeiffer 1980; Ziembińska-Tworzydło et al., p. 38, pl. 11, fig. 9 (Poland, Middle Miocene).
1996 *Aceripollenites striatus* (Pflug 1959) Thiele-Pfeiffer 1980; Ashraf & Mosbrugger, p. 35, pl. 6, figs 6, 7 (Germany, Lower Rhine Bay, Neogene).

Size. 30–45 µm, $\bar{x} = 38$ µm (n = 4)

Description. Tricolpate pollen grains in circular outline in polar view, in broadly oval elongate outline in equatorial view. Colpi running to the poles. Exine semitectate, striate. Striae arranged mostly meridionally.

Stratigraphic occurrence. From Eocene to Pliocene in Europe and some localities of Asia.

Occurrence in Shanwang. Frequent occurrence but in very small numbers.

Botanical affinity. Aceraceae, *Acer platanoides* L., *A. pseudoplatanus* L. and *A. campestre* L. (Thiele-Pfeiffer 1980) or *A. rubrum* L. (Mohr 1984).

Genus ***Operculumpollis*** Sun, Kong & Li 1980

Type. *Operculumpollis operculatus* Sun, Kong & Li 1980

(51) ***Operculumpollis operculatus*** Sun, Kong & Li 1980

Pl. 5, fig. 15a–c

1978 *Trochodendron* sp.; IPEDPMPI-NIGPAS, p. 117, 118, pl. 39, figs 1–5 (China, Bohai coastal region, Early Tertiary).
1980 *Operculumpollis operculatus* n. gen. n. sp.; Sun et al., p. 193, pl. 1, figs 31–35 (South China Sea, Early Tertiary).
1981 *Operculumpollis operculatus* Sun, Kong & Li 1980; Sun et al., p. 46, pl. 17, fig. 49 (China, North continental shelf of South China Sea, Tertiary).

Size. 24 µm (n = 1)

Description. Tricolpate pollen grain in circular-trilobate shape in polar view. Colpi almost extend to the poles, with wedge-shaped opercula. Exine about 2 µm thick, semitectate, reticulate. Lumina show a slight and very gradual decrease towards the colpi.

Stratigraphic occurrence. Several Tertiary localities in China (cf. Song et al. 1999).

Occurrence in Shanwang. Only single specimen has been found in the middle part of profile.

Botanical affinity. Trochodendraceae, *Trochodendron* Sieb. & Zucc. (Sun et al. 1980).

Genus ***Ranunculacidites*** Sah 1967

Type. *Ranunculacidites communis* Sah 1967

(52) ***Ranunculacidites pachydermus*** Zheng 1989

Pl. 5, fig. 2; Pl. 7, fig. 15

1978 *Ranunculaceae* type 1; IPEDPMPI-NIGPAS, p. 119, pl. 40, figs 1–4 (China, Bohai coastal region, Early Tertiary).
1989 *Ranunculacidites pachydermus* Zheng n. sp.; Guan et al., p. 101, pl. 36, figs 2, 3 (China, Region around Bohai sea, Late Cenozoic).

Size. 23–30 μm, $\bar{x}$ = 26 μm (n = 4)

Description. Tricolpate pollen grains in circular outline in polar view. Colpi widely open, with entire membrane. Margins of colpi slightly thickened. Exine thick. Surface and membrane granulate sculpture.

Stratigraphic occurrence. Bohai sea, East China, from Miocene to Pleistocene (cf. Song et al. 1999).

Occurrence in Shanwang. Very rare.

Botanical affinity. Ranunculaceae (Song et al. 1999).

(53) ***Ranunculacidites vulgaris*** Song & G.X. Li 1989

Pl. 7, fig. 14a, b

1989 *Ranunculacidites vulgaris* Song & G.X. Li n. sp.; Song & Qian, p. 120, pl. 42, figs 15–17 (China, Subei Basin, Early Tertiary).
1989 *Ranunculacidites vulgaris* Song & G.X. Li 1989; Guan et al., p. 102, pl. 35, figs 1–7 (East China, Bohai Sea, Miocene to Pliocene).

Size. 37–42 μm, $\bar{x}$ = 40 μm (n = 4)

Description. Tricolpate pollen grains in circular outline in polar position. Colpi with membrane, widely opened. Exine thin, finely granulate sculpture.

Stratigraphic occurrence. Coastal region of East China, from Eocene to Pleistocene (cf. Song et al. 1999).

Occurrence in Shanwang. Frequent occurrence but in very small numbers.

Botanical affinity. Ranunculaceae (Song et al. 1999).

Genus ***Tricolpopollenites*** Pflug & Thomson in Thomson & Pflug 1953

Type. *Tricolpopollenites parmularius* (Potonié 1934) Thomson & Pflug 1953

(54) ***Tricolpopollenites asper*** Pflug & Thomson in Thomson & Pflug 1953

Pl. 4, figs 5–7

1953 *Tricolpopollenites asper* n. sp.; Pflug & Thomson in Thomson & Pflug, p. 96, pl. 11, figs 43–46 (Germany, different source localities, Eocene) and figs 47–49 (Germany, Wallensen, Middle to Upper Pliocene).
1978 *Quercoidites asper* (Thomson & Pflug 1953) Sung & Zheng; IPEDPMPI-NIGPAS, p. 113, pl. 37, figs 7–12 (China, Coastal region of Bohai Sea, Early Tertiary).
1980 *Tricolpopollenites asper* Thomson & Pflug 1953; Thiele-Pfeiffer, p. 143, pl. 11, figs 8–12 (Germany, Oder/Wackersdorf, Miocene).
1984 *Tricolpopollenites asper* Thomson & Pflug 1953; Mohr, p. 76, pl. 12, figs 2.1, 2.2 (Germany, Frechen, Fortuna Garsdorf, from Miocene to Pliocene).
1994 *Quercoidites asper* (Pflug & Thomson 1953) Słodkowska n. comb.; Ziembińska-Tworzydło et al., p. 26, pl. 15, figs 1, 2 (Poland, Neogene).
1996 *Quercoidites asper* Thomson & Pflug 1953; Ashraf & Mosbrugger, p. 28, pl. 5, fig. 7 (Germany, Lower Rhine Bay, Neogene).

Size. 20–26 μm, $\bar{x}$ = 23 μm (n = 5)

Description. This is a collective species for pollen of quercoidal type. Tricolpate or tricolporoidate pollen grains in circular or broadly elliptic outline in equatorial view. Colpi run parallel or convergent in the poles. Exine coarsely granulate.

Stratigraphic occurrence. Uncertain in the Eocene, frequent in Miocene and Pliocene in central Europe (Mohr 1984). Tertiary in China (Song et al. 1999).

Occurrence in Shanwang. Frequent in the entire profile but not numerous.

Botanical affinity. Fagaceae, *Quercus* L. (Thomson & Pflug 1953).

(55) ***Tricolpopollenites henrici*** (Potonié 1931) Thomson & Pflug 1953

Pl. 4, fig. 11

1931b *Pollenites henrici* n. sp.; Potonié, p. 332, pl. 2, fig. 19 (Germany, Muskau Babina mine – since 1945 Poland, Miocene).

1953 *Tricolpopollenites henrici* (Potonié 1931) n. comb.; Thomson & Pflug, p. 95, pl. 11, figs 30–42 (Germany, different source localities, from Eocene to Miocene).
1978 *Quercoidites henrici* (Potonié 1931) Potonié, Thomson & Thiergart 1950; IPEDPMPI-NIGPAS, p. 113, pl. 37, fig. 6 (China, Coastal region of Bohai Sea, Early Tertiary).
1980 *Tricolpopollenites henrici* (Potonié 1931) Thomson & Pflug 1953; Thiele-Pfeiffer, p. 142, pl. 11, figs 1, 2 (Germany, Oder/Wackersdorf, Miocene).
1994 *Quercoidites henrici* (Potonié 1931) Potonié, Thomson & Thiergart 1950; Ziembińska-Tworzydło et al., p. 26, pl. 15, figs 7, 8 (Poland, Oligocene to Miocene).

S i z e. 30×20 µm (n = 1)

D e s c r i p t i o n. Tricolpate or tricolporoidate pollen grain in elliptic shape in equatorial view. Colpi extend parallel towards and converge at the poles. Exine granulate.

S t r a t i g r a p h i c o c c u r r e n c e. Uncertain in Eocene, abundant in Oligocene and Miocene (cf. Thiele-Pfeiffer 1980); Tertiary in China (Song et al. 1999).

O c c u r r e n c e i n S h a n w a n g. Sporadic throughout the entire profile.

B o t a n i c a l a f f i n i t y. Probably Fagaceae, *Quercus* L. (Potonié, Thomson & Thiergart 1950).

(56) ***Tricolpopollenites microhenrici*** (Potonié 1931) Thomson & Pflug 1953

Pl. 7, fig. 7a, b

1931a *Pollenites microhenrici* n. sp.; Potonié, p. 26, pl. 1, fig. 19c (Germany, Ville Beissels mine, Miocene).
1950 *Quercoidites microhenrici* (Potonié 1931) n. comb.; Potonié, Thomson & Thiergart, p. 55, pl. B, figs 24, 25; pl. C, fig. 22 (Germany, Ville, Fortuna, Ellenhausen, Westerwald, Miocene).
1953 *Tricolpopollenites microhenrici* (Potonié 1931) n. comb.; Thomson & Pflug, p. 96, pl. 11, figs 62–110 (Germany, different source localities, from Eocene to Pliocene).
1978 *Quercoidites microhenrici* (Potonié 1931) Potonié; IPEDPMPI-NIGPAS, p. 113, pl. 36, figs 48–53 (China, Coastal region of Bohai, Early Tertiary).
1980 *Tricolpopollenites microhenrici* (Potonié 1931) Thomson & Pflug 1953; Thiele-Pfeiffer, p. 142, pl. 11, figs 3–7 (Germany, Oder/Wackersdorf, Miocene).
1989 *Quercoidites microhenrici* (Potonié 1931) Potonié; Guan et al., p. 82, pl. 25, figs 10, 11 (China, Region around Bohai Sea, Miocene to Pliocene).
1994 *Quercoidites microhenrici* (Potonié 1931) Potonié, Thomson & Thiergart 1950; Ziembińska-Tworzydło et al., p. 40, pl. 15, figs 5, 6 (Poland, Rzeszów, Middle Miocene).
1996 *Quercoidites microhenrici* (Potonié 1931) Potonié, Thomson & Thiergart 1950; Ashraf & Mosbrugger, p. 28, pl. 5, fig. 11 (Germany, Lower Rhine Bay, Neogene).

S i z e. 22–28×16–21 µm, $\overline{x}$ = 25×18 µm (n = 4)

D e s c r i p t i o n. This is a collective species including small tricolpate or tricolporoidate pollen grains, which is supposed to be related to the living representatives of the genus *Quercus*, often in elliptic outline in equatorial view. Exine coarsely or finely granulate.

S t r a t i g r a p h i c o c c u r r e n c e. From Eocene to Miocene, rare in Pliocene in Europe (Thomson & Pflug 1953, Leschik 1956). Tertiary in China (Song et al. 1999).

O c c u r r e n c e i n S h a n w a n g. Sporadic throughout the entire profile.

B o t a n i c a l a f f i n i t y. Fagaceae, *Quercus* L. (Thomson & Pflug 1953).

(57) ***Tricolpopollenites minimireticulatus*** Trevisan 1967

Pl. 5, fig. 1

1967 *Tricolpopollenites minimireticulatus* n. fsp.; Trevisan, p. 38, pl. 24, figs 10–12 (Italy, Toscana, Miocene)
1972 *Labiatae* 2; Planderová, p. 265, pl. 44, figs 7–9 (Southern Slovakia, Carpathians mountains, Pliocene).
1984 *Tricolpopollenites minimireticulatus* Trevisan 1967; Mohr, p. 78, pl. 12, fig. 11 (Germany, Rhine brown coal, Upper Miocene to Lower Pliocene).
1994 *Cercidiphyllites minimireticulatus* (Trevisan 1967) Ziembińska-Tworzydło n. comb.; Ziembińska-Tworzydło et al., p. 21, pl. 13, fig. 2 (Poland, Neogene).

S i z e. 27–35 µm, $\overline{x}$ = 32 µm (n = 3)

D e s c r i p t i o n. Tricolpate pollen grains in circular outline in polar view. Long and wide colpi often covered with the fine membrane. Small polar area. Exine thin, finely reticulate sculpture.

S t r a t i g r a p h i c o c c u r r e n c e. In Miocene (Trevisan 1967, Mohr 1984) and Pliocene (Planderová 1972).

O c c u r r e n c e i n S h a n w a n g. Frequent occurrence but not numerous.

B o t a n i c a l a f f i n i t y. Uncertain. Labiatae (Stuchlik 1964, Planderová 1972) or Cercidiphyllaceae, *Cercidiphyllum* Sieb. & Zucc. (Mohr 1984).

(58) ***Tricolpopollenites*** cf. ***sinuosimuratus*** Trevisan 1967

Pl. 5, fig. 4a, b

1967 *Tricolpopollenites sinuosimuratus* n. fsp.; Trevisan, p. 38, pl. 25, fig. 4 (Italy, Toscana, Upper Miocene).
1984 *Tricolpopollenites* cf. *sinuosimuratus* Trevisan 1967; Mohr, p. 78, pl. 12, figs 10.1, 10.2, 13.1, 13.2 (Germany, Lower Rhine Bay, Fortuna Garsdorf, Miocene, Pliocene).
1996 *Tricolpopollenites* cf. *sinuosimuratus* Trevisan 1967; Ashraf & Mosbrugger, p. 33, pl. 6, figs 1–3 (Germany, Lower Rhine Bay, Neogene).

Size. 22×18 µm (n = 1)

Description. Tricolpate pollen grain in broadly elliptic outline in equatorial view. Colpi short narrow. Exine very thin, finely reticulate sculpture.

Stratigraphic occurrence. Previously reported only in Upper Miocene from Messin, Italy (Trevisan 1967), and Upper Miocene to Lower Pliocene of Germany (Mohr 1984).

Occurrence in Shanwang. Very rare.

Botanical affinity. Uncertain. Oleaceae, *Fraxinus* L. (Trevisan 1967, Mohr 1984).

(59) ***Tricolpopollenites* sp. 1**

Pl. 4, fig. 2

Size. 27×22 µm, (n = 1)

Description. Tricolpate or tricolporoidate pollen grain in broadly elliptic outline in equatorial view. Colpi staight, run parallel and almost reach to the poles. Exine tectate, sexine is thicker than nexine. Coarsely granulate sculpture.

Occurrence in Shanwang. Rare.

Botanical affinity. Unknown.

(60) ***Tricolpopollenites* sp. 2**

Pl. 4, fig. 3

Size. 22×15 µm, (n = 1)

Description. Small tricolpate or tricolporoidate pollen grain in elliptic outline in equatorial view. Colpi almost straight, run parallel and almost reach to the poles. Exine thick, sexine is thicker than nexine. Surface almost psilate sculpture.

Occurrence in Shanwang. Rare.

Botanical affinity. Unknown.

(61) ***Tricolpopollenites* sp. 3**

Pl. 4, figs 17a–c, 18a–c

Size. 18–24×16–20 µm, $\bar{x}$ = 22×18 µm (n = 4)

Description. Small tricolpate or tricolporoidate pollen grains in oval to circular outline in equatorial view. Colpi reach and converge at the poles. Polar areas very rounded. Exine semitectate, reticulate. Lumina small, showing a slight and very gradual decrease towards the colpi.

Occurrence in Shanwang. Frequent occurrence but not numerous.

Botanical affinity. Unknown.

<u>Tricolporate (P:E</u> > 1) pollen grains

Genus ***Alangiopollis*** Krutzsch 1962

Type. *Alangiopollis barghoornianum* (Traverse 1955) Krutzsch 1962

(62) ***Alangiopollis barghoornianum*** (Traverse 1955) Krutzsch 1962

Pl. 9, fig. 1a, b

1955 *Alangium barghoornianum* n. sp.; Traverse, p. 64, pl. 12, fig. 102 (USA, Middle Tertiary).
1962 *Alangiopollis barghoornianum* (Traverse 1955) n. comb.; Krutzsch, p. 279, 280, pl. 7, figs 1–9 (Germany, different source localities, Middle Oligocene and Lower Miocene).
1978 *Retitricolporites magnus* Ke & Shi n. sp.; IPEDPMPI-NIGPAS, p. 156, pl. 57, figs 28, 29 (Upper Eocene to Oligocene).
1985 *Alangiopollis barghoornianum* (Traverse 1955) Krutzsch 1962; Nagy, p. 160, pl. 92, figs 1–4 (Hungary, Egerian and Eggenburgian).
1986 *Alangiopollis* cf. *barghoornianum* (Traverse 1955) Krutzsch 1962; Liu, pl. 3, fig. 43 (China, Shandong Shanwang, Yaoshan Formation, Miocene).
1994 *Alangiopollis barghoornianum* (Traverse 1955) Krutzsch 1962; Ziembińska-Tworzydło et al., p. 38, pl. 11, figs 12, 13 (Poland, Lower Miocene).
1998 *Alangiopollis barghoornianum* (Traverse 1955) Krutzsch 1962; Bruch, p. 96, pl. 14, figs 1, 2 (Slovenia, Oligocene).

Size. 40 µm (n = 1)

Description. Tricolporate pollen grain in circular outline in polar view. Colpi wide-opened, pores large. Exine semitectate, reticulate. Lumina large, showing a gradual decrease towards the colpi. Surface characteristical striato-reticulate sculpture. For more detailed description see Krutzsch (1962).

Stratigraphic occurrence. From Lower Oligocene to Pliocene in Europe (cf. Bruch 1998); Upper Eocene to Oligocene in eastern China (cf. Song et al. 1999).

Occurrence in Shanwang. Only single specimen has been found from middle part of the profile.

Botanical affinity. Alangiaceae, *Alangium kurzii* Craib (Krutzsch 1962, Nagy 1985).

Genus ***Artemisiaepollenites*** Nagy 1969

Type. *Artemisiaepollenites sellularis* Nagy 1969

(63) ***Artemisiaepollenites sellularis*** Nagy 1969

Pl. 8, figs 12a, b, 13; Pl. 9, fig. 2a–c

1969 *Artemisiaepollenites sellularis* n. gen. n. sp.; Nagy, p. 208 (440), pl. 41, figs 18, 19; pl. 49, figs 16, 17 (Southern Hungary, Mecsek Mountains, Miocene).

1985 *Artemisiaepollenites sellularis* Nagy 1969; Nagy, p. 184, 185, pl. 107, figs 1–5 (Hungary, Miocene).

1985 *Artemisiaepollenites sellularis* Nagy 1969; Song et al., p. 102, 103, pl. 34, figs 5–11 (China, Longjing Structural Area in the Shelf Basin of the East China Sea Region, Pliocene).

1989 *Artemisiaepollenites sellularis* Nagy 1969; Guan et al., p. 72, pl. 22, figs 13–19 (China, Region around Bohai Sea, Miocene to Pleistocene).

1994 *Artemisiaepollenites sellularis* Nagy 1969; Ziembińska-Tworzydło et al., p. 38, pl. 11, figs 10, 11 (Poland, Neogene).

Size. 15–22 μm, $\bar{x} = 19$ μm (n = 4)

Description. Small tricolporate pollen grains in circular outline in equatorial and polar view. Exine tectate, with regularly spaced verrucae on the tectum. Columellae underlying varying in thickness, with the coarse columellae occupying the centre of the mesocolpia, finer shorter columellae near the colpus margins.

Stratigraphic occurrence. In the Miocene of Hungary (Nagy 1969); Several localities in China from Miocene to Pleistocene (cf. Song et al. 1999).

Occurrence in Shanwang. Rare. Only several specimens have been found.

Botanical affinity. Asteraceae (Compositae), *Artemisia* L. (Nagy 1969).

Genus ***Eucommiaceoipollenites*** M.R. Sun 1989

Type. *Eucommiaceoipollenites eucommides* M. R. Sun 1989

(64) ***Eucommiaceoipollenites eucommides*** M. R. Sun 1989

Pl. 6, fig. 4

1989 *Eucommiaceoipollenites eucommides* M. R. Sun n. gen. n. sp.; Sun et al., p. 77, pl. 26, figs 16–19 (China, Shelf basin of the East China Sea, Palaeocene).

1990 *Tricolporopollenites eucommii* n. sp.; Planderová, p. 70, 71, pl. 69, figs 22–29 (Slovakia, Central Paratethys, Miocene).

1996 *Tricolporopollenites parmularius* (Potonié 1934) Krutzsch in Krutzsch, Pchalek & Spiegler 1960; Ashraf & Mosbrugger, p. 42, pl. 7, fig. 10 (Germany, Lower Rhine Bay, Neogene).

Size. 25–34×17–24 μm, $\bar{x} = 30 \times 20$ μm (n = 5)

Description. Tricolporate or tricolporoidate pollen grains in elliptic outline in equatorial view. Polar areas are rounded. Colpi running subparallel, not reaching to the poles. Colpi in different length and the middle one is the shortest. Exine tectate, psilate.

Stratigraphic occurrence. From Eocene to Pliocene, frequent in Pliocene (cf. Mohr 1984), and Palaeocene of eastern China (Song et al. 1999).

Occurrence in Shanwang. Frequent through the whole profile, especially abundant in the upper part.

Botanical affinity. Eucommiaceae, it is very similar to the extant species *Eucommia ulmoides* Oliv. (Mohr 1984).

Genus ***Faguspollenites*** Raatz 1937 ex Potonié 1960

Type. *Faguspollenites verus* Raatz 1937 ex Potonié 1960

(65) ***Faguspollenites crassus*** Nagy 1969

Pl. 8, figs 1a, b, 2; Pl. 9, fig. 7

1969 *Faguspollenites crassus* n. sp.; Nagy, p. 231, 232 (463, 464), pl. 52, fig. 20 (Hungary, Mecsek Mountain, Miocene).

1985 *Faguspollenites crassus* Nagy 1969; Nagy, p. 199, pl. 113, figs 1–5 (Hungary, Miocene).

Size. 30–32 μm, $\bar{x} = 31$ μm (n = 3)

Description. Tricolporate pollen grains in circular outline in polar view. Exocolpi narrow, short. Endopores with characteristical costae. Exine granulate. Different from other *Faguspollenites* species in its pore structure.

Stratigraphic occurrence. Miocene in Hungary (Nagy 1969).

Occurrence in Shanwang. Sporadic in upper part of the profile.

Botanical affinity. Fagaceae, *Fagus* L. (Nagy 1969).

(66) ***Faguspollenites gemmatus*** Nagy 1969

Pl. 8, figs 6a–c, 8, 9; Pl. 9, fig. 4

1969 *Faguspollenites gemmatus* n. sp.; Nagy, p. 231 (463), pl. 51, figs 18, 19 (Hungary, Mecsek, Tortonian, Miocene).
1985 *Faguspollenites gemmatus* Nagy 1969; Nagy, p. 199, 200, pl. 113, figs 13, 14 (Hungary, Mocene).

Size. 36–45 µm, $\bar{x} = 41$ µm (n = 3)

Description. Tricolporate pollen grains in circular outline in polar view. Exocolpi narrow, short. Endopores circular. Exine gemmate. Different from other *Faguspollenites* in its coarsely gemmate sculpture.

Stratigraphic occurrence. Miocene in Hungary (Nagy 1969).

Occurrence in Shanwang. Sporadic in upper part of the profile.

Botanical affinity. Fagaceae, probably closely related to *Fagus orientalis* Lipsky (Nagy 1969).

(67) ***Faguspollenites subtilis*** Nagy 1969

(Without figure)

1969 *Faguspollenites subtilis* n. sp.; Nagy, p. 230 (462), pl. 52, fig. 14 (Hungary, Mecsek Mountains, Miocene).
1985 *Faguspollenites subtilis* Nagy 1969; Nagy, p. 200, pl. 113, figs 13, 14 (Hungary, Miocene).

Size. 50 µm (n = 1)

Description. Tricolporate pollen grain in circular outline in polar view. Exine very thin, finely granulate. Different from other *Faguspollenites* in its large size.

Stratigraphic occurrence. Miocene in Hungary (Nagy 1969).

Occurrence in Shanwang. Rare.

Botanical affinity. Fagaceae, *Fagus* L., *Fagus sylvatica* L. (Nagy 1969).

(68) ***Faguspollenites verus*** Raatz 1937 ex Potonié 1960

Pl. 8, figs 3a, b, 4a, b, 5a, b, 7a, b; Pl. 9, fig. 5

1937 *Fagus-pollenites verus* n. sp.; Raatz, p. 23, pl. 1, fig. 17 (Germany, Upper Lusatia, Miocene).
1980 *Faguspollenites verus* Raatz 1937; Thiele-Pfeiffer, p. 161, pl. 15, figs 4, 5 (Germany, Oder/Wackersdorf, Miocene).
1985 *Faguspollenites verus* Raatz 1937; Nagy, p. 200, pl. 113, figs 15, 16 (Hungary, Egerian).
1985 *Faguspollenites mediocris* Zheng n. sp.; Song et al., p. 113, pl. 38, figs 36, 37, 42–44 (China, Longjing Structural Area in the Shelf Basin of East China Sea Region, Miocene to Pliocene).
1989 *Faguspollenites mediocris* Zheng 1985; Guan et al., p. 81, pl. 26, figs 13–17 (China, Region around Bohai Sea, Miocene to Pleistocene).
1989 *Cornaceoipollenites subrotundus* Zheng n. sp.; Guan et al., p. 76, pl. 23, figs 15–25 (China, Region around Bohai Sea, Miocene to Pleistocene).
1994 *Faguspollenites verus* Raatz 1937 ex Potonié 1960; Ziembińska-Tworzydło et al., p. 39, pl. 14, figs 1, 2 (Poland, Neogene).
1996 *Faguspollenites verus* Raatz 1937; Ashraf & Mosbrugger, p. 47, pl. 7, figs 21, 22 (Germany, Lower Rhine Bay, Neogene).

Size. 37–39 µm, $\bar{x} = 38$ µm (n = 3)

Description. Tricolporate pollen grains in circular outline in polar view. Exocolpi narrow, short. Endopores circular. Exine granulate.

Stratigraphic occurrence. From Upper Oligocene to Pliocene (Mohr 1984).

Occurrence in Shanwang. Abundant in the upper part of the profile.

Botanical affinity. Fagaceae, *Fagus* L.. According to Raatz (1937), the delicately granulate form is close to pollen grains of the extant species *F. sylvatica* L. and *F. ferruginea* Ait, while the coarsely granulate form is close to pollen grains of *F. orientalis* Lipsky.

Genus ***Horniella*** Traverse 1955 emend. Song 1999

Type. *Horniella clavaticosta* Traverse 1955

(69) ***Horniella fusiformis*** (Song & Qian 1989) Song 1999

Pl. 7, fig. 11a–c

1989 *Rutaceoipollis fusiformis* Song & Qian n. sp.; Song & Qian, p. 74, pl. 18, fig. 20; pl. 19, fig. 12; pl. 26, fig. 2 (China, Subei Basin, Palaeocene).
1998 *Tricolporopollenites* sp. reticulate Form 1; Bruch, p. 88, pl. 12, figs 15–17 (Slovenia, Oligocene).

1999 *Horniella fusiformis* (Song & Qian) n. comb.; Song et al., p. 457, pl. 122, figs 4–6 (China, Subei Basin, Palaeocene).

Size. 35×26 µm (n = 1)

Description. Tricolporate pollen grain in elliptic outline in equatorial view, polar areas sharped. Colpi thick-edged, reaching and converging at the poles. Pores slightly equatorial elongated. Exine semitectate, reticulate.

Occurrence in Shanwang. Only single specimen has been found in the middle part of the profile.

Botanical affinity. Uncertain. Song et al. (1999) considers that it relates to Rutaceae or Rubiaceae.

Genus ***Ilexpollenites*** Thiergart 1937 ex Potonié 1960

Type. *Ilexpollenites iliacus* (Potonié 1931) Thiergart 1937 ex Potonié 1960

(70) ***Ilexpollenites propinquus*** (Potonié 1934) Potonié 1960

Pl. 4, fig. 14a–c

1934 *Pollenites propinquus* n. sp.; Potonié, p. 74, pl. 3, fig. 33 (Germany, Geiseltal, Eocene).

1960 *Ilexpollenites* (al. *Pollenites*) *propinquus* (Potonié 1934) n. comb.; Potonié, p. 100 (Germany, Geiseltal, Eocene).

1969 *Ilexpollenites propinquus* (Potonié 1934) Potonié 1960; Nagy, p. 183 (415), pl. 43, fig. 9 (Hungary, Mecsek, Miocene).

1985 *Ilexpollenites propinquus* (Potonié 1934) Potonié 1960; Nagy, p. 168, pl. 96, figs 17–19 (Hungary, Miocene).

1994 *Ilexpollenites propinquus* (Potonié 1934) Potonié 1960; Ziembińska-Tworzydło et al., p. 39, pl. 14, fig. 8 (Poland, Miocene).

Size. 20 µm (n = 1)

Description. Small tricolporate or tricolporoidate pollen grains, circular outline in equatorial view. Colpi reaching to the poles. Exine tectate, clavate. Surface reticulate.

Stratigraphic occurrence. Eocene (Potonié 1960) and Miocene (Ziembińska-Tworzydło 1974, Nagy 1985).

Occurrence in Shanwang. Sporadic.

Botanical affinity. Aquifoliaceae, *Ilex* L. (Potonié 1960, Nagy 1985).

Genus ***Nyssapollenites*** Thiergart 1937 ex Potonié 1960

Type. *Nyssapollenites pseudocruciatus* (Potonié 1931) Thiergart 1937

(71) ***Nyssapollenites kruschi*** (Potonié 1931) Potonié, Thomson & Thiergart 1950 ssp. ***accessorius*** (Potonié 1934) Potonié, Thomson & Thiergart 1950

Pl. 8, fig. 10a, b; Pl. 9, fig. 6

1931d *Pollenites kruschi* n. sp.; Potonié, p. 3, 4, fig. 11 (Germany, Beissels mine, Babina mine – since 1945 Poland, Miocene).

1934 *Pollenites kruschi* (Potonié 1931) *accessorius* n. ssp.; Potonié, p. 64, 65, pl. 6, fig. 9 (Germany, Geiseltal, Middle Eocene).

1950 *Nyssapollenites* (*kruschi*) *accessorius* (Potonié 1934); Potonié, Thomson & Thiergart, p. 59, pl. B, fig. 48 (Germany, Wallensen, Pliocene).

1953 *Tricolporopollenites kruschi* (Potonié 1931) n. comb. ssp. *accessorius* (Potonié 1934) n. comb.; Thomson & Pflug, p. 103, 104, pl. 13, figs 27, 31 (Germany, different source localities, Miocene).

1980 *Nyssapollenites kruschi* (Potonié 1931) Nagy 1969; Thiele-Pfeiffer, p. 161, pl. 15, figs 1–3 (Germany, Oder/Wackersdrof, Miocene).

1996 *Nyssapollenites kruschi* (Potonié 1931) Potonié, Thomson Thiergart 1950 ssp. *accessorius* (Potonié 1934) Potonié, Thomson & Thiergart 1950; Ashraf & Mosbrugger, p. 48, pl. 8, figs 4–6 (Germany, Lower Rhine Bay, Neogene).

Size. 30–33 µm, $\overline{x}$ = 31 µm (n = 3)

Description. Tricolporate pollen grains in circular outline in equatorial and polar view. Colpi convergent and tapering towards the poles. Pores round, surrounded by colpi. Exine tectate, perforate.

Stratigraphic occurrence. From Eocene to Pliocene in Europe, abundant during the Miocene (cf. Thiele-Pfeiffer 1980).

Occurrence in Shanwang. Sporadic in upper part of the profile.

Botanical affinity. Nyssaceae, *Nyssa* L. (Thiele-Pfeiffer 1980).

(72) ***Nyssapollenites kruschi*** (Potonié 1931) Potonié, Thomson & Thiergart 1950 ssp. ***analepticus*** (Potonié 1934) Nagy 1969

Pl. 8, fig. 11a, b; Pl. 9, fig. 3a, b

1934 *Pollenites kruschi analepticus* n. ssp.; Potonié, p. 65, without figure (Germany, Geiseltal, Middle Eocene).

1953 *Nyssapollenites kruschi* (Potonié 1931) n. comb. ssp. *analeptics* (Potonié 1934) n. comb.; Thomson & Pflug, p. 103, 104, pl. 13, figs 14–24 (Germany, different source localities, from Palaeocene to Miocene).
1969 *Nyssapollenites kruschi* (Potonié 1931) ssp. *analeptics* (Potonié 1934) n. comb.; Nagy, p. 177 (409), without figure (Hungary, Lower to Middle Miocene).
1981 *Nyssapollenties analepticus* (Potonié 1934) Potonié 1951; Song et al., p. 141, pl. 52, fig. 13 (China, Jiangsu areas, Eocene to Oligocene).
1996 *Nyssapollenites kruschi* (Potonié 1931) Potonié, Thomson & Thiergart 1950 ssp. *analepticus* (Potonié 1934) Nagy 1969; Ashraf & Mosbrugger, p. 49, pl. 8, fig. 7 (Germany, Lower Rhine Bay, Neogene).

Size. 23–28 µm, $\bar{x} = 25$ µm (n = 4)

Description. Tricolporate pollen grains in circular outline in equatorial and polar view. According to (Thomson & Pflug 1953), different from *Nyssapollenites kruschi accessorius* only in its small size.

Stratigraphic occurrence. From Eocene to Pliocene in Europe, abundant during Miocene (cf. Thiele-Pfeiffer 1980).

Occurrence in Shanwang. Sporadic in upper part of the profile.

Botanical affinity. Probably Nyssaceae, *Nyssa* L. According to Mohr (1984), the small pollen form of *Nyssapollenites kruschi* also possibly belongs to Vitaceae.

(73) ***Nyssapollenites kruschi*** (Potonié 1931) Potonié, Thomson & Thiergart 1950 ssp. ***rodderensis*** (Thiergart 1937) **comb. nov.**

Pl. 7, fig. 3

1953 *Tricolporopollenites kruschi* (Potonié 1931) ssp. *rodderensis* (Thiergart 1937) n. comb.; Thomson & Pflug, p. 104, pl. 13, figs 32, 33 (Germany, different source localities, Upper Oligocene to Lower Miocene).
1993 *Tricolporopollenites kruschi* (Potonié 1931) ssp. *rodderensis* (Thiergart 1937) Thomson & Pflug 1953; Kohlman-Adamska, p. 147, pl. 24, figs 4, 5 (North-western Poland, Wyrzysk region, Neogene).

Size. 39 µm (n = 1)

Description. Tricolporate pollen grain in slightly prolate circular outline in equatorial view. According to Thomson & Pflug (1953), different from *Nyssapollenites kruschi accessorius* only in its bigger size.

Stratigraphic occurrence. From Oligocene to Pliocene (Thomson & Pflug 1953).

Occurrence in Shanwang. Sporadic in upper part of the profile.

Botanical affinity. Nyssaceae, *Nyssa* L. (Thomson & Pflug 1953).

Genus ***Oleoidearumpollenites*** Nagy 1969

Type. *Oleoidearumpollenites reticulatus* Nagy 1969

(74) ***Oleoidearumpollenites microreticulatus*** (Pflug & Thomson 1953) Ziembińska-Tworzydło 1994

Pl. 5, fig. 14a–c

1953 *Tricolporopollenites microreticulatus* n. sp. f. *globosa* n. f.; Pflug & Thomson in Thomson & Pflug, p. 106, pl. 14, figs 35–39 (Germany, different source localities, from Eocene to Miocene).
1956 *Tricolpo-pollenites retiformis* Pflug & Thomson; Meyer, p. 109, 127, pl. 3, figs 34–36 (Germany, Wackersdorf, Miocene).
1978 *Fraxinoipollenites microreticulatus* Ke & Shi n. sp.; IPEDPMPI-NIGPAS, p. 141, pl. 49, figs 10–16 (China, Coastal region of Bohai Sea, Upper Eocene to Oligocene).
1980 *Tricolporopollenites microreticulatus* Thomson & Pflug 1953; Thiele-Pfeiffer, p. 154, 155, pl. 13, figs 1–11 (Germany, Oder/Wackersdorf, Miocene).
1985 *Fraxinoipollenites microreticulatus* Ke & Shi 1978; Zhu Z.H. et al., p. 179, pl. 56, figs 9–16 (Northwest China, Qaidamu Basin, Oligocene to Miocene).
1994 *Oleoidearumpollenites microreticulatus* (Pflug & Thomson 1953) Ziembińska-Tworzydło n. comb.; Ziembińska-Tworzydło et al., p. 25, pl. 14, fig. 18a-c (Poland, Neogene).
1996 *Tricolporopollenites microreticulatus* Thomson & Pflug 1953; Ashraf & Mosbrugger, p. 42, pl. 7, figs 3, 4 (Germany, Lower Rhine Bay, Neogene).

Size. 20–22 µm, $\bar{x} = 20$ µm (n = 4)

Description. Small tricolporate pollen grains in circular outline in polar view. Colpi running deeply into the polar areas. Exine semitectate, reticulate. Lumina in the shape of irregular polygons.

Stratigraphic occurrence. Based on the synonym of this pollen form, it ranges from the Palaeocene to Pliocene in central and eastern Europe (cf. Thiele-Pfeiffer 1980). Several localities from Eocene to Pliocene in China (cf. Song et al. 1999).

Occurrence in Shanwang. Sporadic.

Botanical affinity. Oleaceae, *Fraxinus* L. (Thiele-Pfeiffer 1980).

(75) ***Oleoidearumpollenites reticulatus*** Nagy 1969

Pl. 6, fig. 5a, b

1969 *Oleoidaerumpollenites reticulatus* n. gen. n. sp.; Nagy, p. 197 (429), pl. 47, figs 2, 3 (Hungary, Mecsek Mountain, Miocene).
1989 *Oleoidaerumpollenites reticulatus* Nagy 1969; Guan et al., p. 95, pl. 33, figs 9–13 (China, Region around Bohai Sea, Miocene to Pleistocene).

Size. 30–40 µm, $\bar{x} = 35$ µm (n = 5)

Description. Tricolporate pollen grains in circular outline in polar view. Exine semitectate, reticulate. Lumina in the shape of irregular polygons. Muri thick, more or less straight, supported by thick clavae. The clavae are 3–4 µm high, standing wide apart in one row.

Stratigraphic occurrence. Tertiary, mainly in Neogene (Song et al. 1999).

Occurrence in Shanwang. Sporadic.

Botanical affinity. Oleaceae (Nagy 1969).

Genus ***Pokrovskaja*** Boitzova 1979 emend. Zhu 1985

Type. *Pokrovskaja originalis* Boitzova 1979

(76) ***Pokrovskaja originalis*** Boitzova 1979

Pl. 9, figs 8a, b, 9a–c

1978 *Meliaceoidites rhomboiporus* Wang n. sp.; IPEDPMPI-NIGPAS, p. 126, pl. 43, figs 6, 7, 10–16, 18 (China, Coastal region of Bohai Sea, Early Tertiary).
1979 *Pokrovskaja originalis* Boitzova n. sp.; Boitzova et al., p. 56, pl. 10, fig. 22; pl. 11, fig. 2 (Russia, Siberia, Upper Eocene).
1985 *Nitrariadites communis* Zhu & Xi Ping n. sp.; Zhu et al., p. 200, pl. 54, figs 11–18; pl. 55, figs 1, 2; pl. 61, fig. 3 (Northwest China, Chaidamu Basin, Qinghai Province, Miocene).

Size. 32–34×25–26 µm, $\bar{x} = 33 \times 26$ µm (n = 2)

Description. Tricolporate pollen grains in elliptic outline in equatorial view. Colpi run parallel to the poles. Pores characteristical rhombic shape, slightly equatorially elongated. Exine about 2.5 µm thick, gradually thicker towards the poles and equatorial plane.

Stratigraphic occurrence. From the Upper Eocene of Siberia and from several localities in China during Early Tertiary (cf. Song et al. 1999).

Occurrence in Shanwang. Sporadic.

Botanical affinity. Zygophyllaceae, *Nitraria* L. (Song et al. 1999).

Genus ***Quercopollenites*** Nagy 1969

Type. *Quercopollenites granulatus* Nagy 1969

(77) ***Quercopollenites granulatus*** Nagy 1969

Pl. 4, fig. 12

1969 *Quercopollenites granulatus* n. gen. n. sp.; Nagy, p. 233 (465), pl. 52, fig. 21 (Hungary, Mecsek Mountain, Miocene).
1985 *Quercopollenites granulatus* Nagy 1969; Nagy, p. 201, pl. 114, figs 4–6 (Hungary, Egerian, Badenian, Pannonian).
1998 *Quercopollenites granulatus* Nagy 1969; Bruch, p. 80, pl. 11, fig. 17 (Slovenia, Oligocene).
1994 *Quercoidites granulatus* (Nagy 1969) Słodkowska n. comb.; Ziembińska-Tworzydło et al., p. 26, pl. 15, figs 10, 11 (Poland, Miocene).

Size. 23–33 µm, $\bar{x} = 28$ µm (n = 4)

Description. Prolate tricolporoidate pollen grains in equatorial view. Colpi straight, parallel and slightly tapering towards the poles. Exine coarsely granulate. Different from *Quercopollenites petraea* type in its straight colpi.

Stratigraphic occurrence. *Quercus*-forms occur throughout the Tertiary (Thomson & Pflug 1953).

Occurrence in Shanwang. Frequent occurrence through the whole profile.

Botanical affinity. Fagaceae, *Quercus robur* L. (Nagy 1969).

(78) ***Quercopollenites petraea*** type Nagy 1969

Pl. 4, figs 9a, b, 10a, b

1969 *Quercopollenites petraea* type; Nagy, p. 234 (466), pl. 53, fig. 18 (Hungary, Mecsek Mountain, Pannonian).
1985 *Quercopollenites petraea* type; Nagy, p. 201, pl. 114, figs 7–9 (Hungary, from Karpatian to Pannonian).
1990 *Quercopollenites petraea* type Nagy 1969; Planderová, p. 68, pl. 67, figs 24–32 (Slovakia, Miocene and Pliocene).
1998 *Quercopollenites petraea* type sensu Nagy 1969; Bruch, p. 80, pl. 11, figs 18, 19 (Slovenia, Oligocene).

Size. 28–37 µm, $\bar{x} = 33$ µm (n = 5)

Description. Prolate, subprolate tricolporoidate pollen grains in equatorial view. Colpi slightly wide, tapering towards but not reaching to the poles. Exine granulate.

Stratigraphic occurrence. *Quercus*-

forms occur throughout the Tertiary (Thomson & Pflug 1953).

Occurrence in Shanwang. Abundant through the whole profile.

Botanical affinity. Fagaceae, *Quercus petraea* L. (Planderová 1990).

(79) ***Quercopollenites robur*** type Nagy 1969

Pl. 4, figs 4a, b; 8a, b

1969 *Quercopollenites robur* type; Nagy, p. 233 (465), pl. 53, fig. 10 (Hungary, Mecsek, Miocene).
1985 *Quercopollenites robur* type; Nagy, p. 201, pl. 114, figs 10, 14 (Hungary, from Egerian to Pannonian).
1990 *Quercopollenites robur* type Nagy 1985; Planderová, p. 68, pl. 57, figs 33–36 (Slovakia, Miocene).
1998 *Quercopollenites robur* type sensu Nagy 1969; Bruch, p. 81, pl. 11, figs 20, 21, 25 (Slovenia, Oligocene).

Size. 24–30 µm, $\bar{x}$ = 27 µm (n = 6)

Description. Prolate, subprolate tricolporoidate pollen grains in equatorial view. Colpi converge and slightly taper toward the poles. Exine finely granulate.

Stratigraphic occurrence. *Quercus*-forms occur throughout the Tertiary (Thomson & Pflug 1953).

Occurrence in Shanwang. Frequent through the whole profile.

Botanical affinity. Fagaceae, *Quercus robur* L. (Nagy 1969).

Genus ***Rhoipites*** Wodehouse 1933

Type. *Rhoipites bradleyi* Wodehouse 1933

(80) ***Rhoipites striatus*** Zheng 1985

Pl. 7, figs 10a, b, 13

1985 *Rhoipites striatus* Zheng n. sp.; Song et al., p. 94, pl. 33, figs 21, 22 (China, Longjing Structural Area in the Shelf Basin of the East China Sea Region, Miocene to Pliocene).
1989 *Rhoipites striatus* Zheng 1985; Guan et al., p. 64, pl. 20, fig. 1 (China, Region around Bohai Sea, Miocene to Pliocene).

Size. 29–34×24–25 µm, $\bar{x}$ = 32×25 µm (n = 2)

Description. Tricolporate pollen grains, broadly elliptic to circular outline in equatorial view. Colpi run and converge at the poles. Round large pores, sometimes slightly equatorially elongated. Surface with distinct meridionally striate sculpture.

Stratigraphic occurrence. Eastern China, Miocene to Pliocene (Song et al. 1999).

Occurrence in Shanwang. Very rare.

Botanical affinity. Anacardiaceae, *Rhus* L. (Song et al. 1999).

Genus ***Rhuspollenites*** Thiele-Pfeiffer 1980

Type. *Rhuspollenites ornatus* Thiele-Pfeiffer 1980

(81) ***Rhuspollenites ornatus*** Thiele-Pfeiffer 1980

Pl. 4, fig. 16a, b

1966 *Tricolporopollenites* sp. *microreticulate* Form 12; Sontag, p. 40, pl. 62, figs 7a–c (Germany, Lower Lusatia, Middle Miocene).
1980 *Rhuspollenites ornatus* n. sp.; Thiele-Pfeiffer, p. 167, 168, pl. 16, figs 15–19, 20–22 (Germany, Wackersdorf, Miocene).

Size. 23×21 µm (n = 1)

Description. Tricolporate pollen grain, broadly oval outline in equatorial view. Colpi running parallel, bending and converging at the poles. Pores strongly equatorially elongated. Exine tectate granulate. Surface finely meridionally striate-reticulate.

Stratigraphic occurrence. Miocene in Wackersdorf and Lower Lusatia, Germany (Sontag 1966, Thiele-Pfeiffer 1980).

Occurrence in Shanwang. Very rare. Only several specimens were found in the middle and upper part of the profile.

Botanical affinity. Anacardiaceae, *Rhus radicans* L., *R. succedanea* L. (Thiele-Pfeiffer 1980).

Genus ***Tricolporopollenites*** Pflug & Thomson in Thomson & Pflug 1953

Type. *Tricolporopollenites dolium* (Potonié 1931) Thomson & Pflug 1953

(82) ***Tricolporopollenites cingulum*** (Potonié 1931) Thomson & Pflug 1953 ssp. ***oviformis*** (Potonié 1931) Thomson & Pflug 1953

Pl. 5, fig. 18a, b

1931b *Pollenites oviformis* n. sp.; Potonié, p. 328, pl. I, fig. 20 (Germany, Geiseltal, Eocene).

1953 *Tricolporopollenites cingulum* (Potonié 1931) n. comb. ssp. *oviformis* (Potonié 1931) n. comb.; Thomson & Pflug, p. 100, pl. 12, figs 42–49 (Germany, Helmstedt, Middle Eocene; Borken, from Upper Eocene to Lower Oligocene).
1978 *Cupuliferoipollenites oviformis* (Potonié 1931) Potonié 1951; IPEDPMPI-NIGPAS, p. 112, pl. 36, figs 33–36 (China, Coastal region of Bohai Sea, Early Tertiary).
1980 *Tricolporopollenites cingulum* (Potonié 1931) Thomson & Pflug 1953 ssp. *oviformis* (Potonié 1931) Thomson & Pflug 1953; Thiele-Pfeiffer, p. 148, pl. 11, figs 44, 45 (Germany, Oder/Wackersdorf, Miocene).
1985 *Tricolporopollenites cingulum* (Potonié 1931) Thomson & Pflug 1953 ssp. *oviformis* (Potonié 1931) Thomson & Pflug 1953; Nagy, p. 203, pl. 114, figs 25, 26 (Hungary, from Miocene to Pliocene).
1994 *Castaneoideaepollis oviformis* (Potonié 1934) Grabowska n. comb.; Ziembińska-Tworzydło et al., p. 21, pl.12, fig. 10 (Poland, Neogene).
1996 *Tricolporopollenites cingulum* (Potonié 1931) Thomson & Pflug 1953 ssp. *oviformis* (Potonié 1931) Thomson & Pflug 1953; Ashraf & Mosbrugger, p. 37, pl. 6, figs 8, 9 (Germany, Lower Rhine Bay, Neogene).

Size. 14–17×11–14 µm, $\bar{x}$ = 16×13 µm (n = 3)

Description. Very small tricolporate pollen grains in broadly elliptic outline in equatorial view. Polar areas are rounded. Colpi run parallel, reach but do not converge at the poles. Exine tectate, psilate.

Stratigraphic occurrence. From the Eocene to Pliocene (Thomson & Pflug 1953), abundant in the Neogene.

Occurrence in Shanwang. Sporadic.

Botanical affinity. Fagaceae, it is similar to pollen forms from Castaneoideae, *Castanea*-type (Thomson & Pflug 1953).

(83) ***Tricolporopollenites*** cf. ***cingulum*** (Potonié 1931) Thomson & Pflug 1953

Pl. 5, figs 12, 13

1931a *Pollenites cingulum* n. sp.; Potonié, p. 26, pl. 1, figs V61c, V60d, V45a, V62c, V52b, V60a, V48b, V46b, V46a, V61b, V46c, V68a (Germany, Ville, Miocene).
1980 *Tricolporopollenites* cf. *cingulum* (Potonié 1931) Thomson & Pflug 1953; Thiele-Pfeiffer, p. 147, pl. 11, figs 35–37 (Germany, Oder/Wackersdorf, Miocene).

Size. 19–23×14–18 µm, $\bar{x}$ = 21×16 µm (n = 3)

Description. Tricolporate pollen grains in broadly elliptic outline in equatorial view. Polar areas are slightly sharp. Colpi curved ourwards in the equatorial plane. Exine thick, tectate psilate. According to Thiele-Pfeiffer (1980), it is similar to *Tricolporopollenites cingulum* ssp. *pusillus* except its curved colpi.

Stratigraphic occurrence. Miocene of Germany, Wackersdorf (Thiele-Pfeiffer 1980).

Occurrence in Shanwang. Rare.

Botanical affinity. Probably Cornaceae (Thiele-Pfeiffer 1980).

(84) ***Tricolporopollenites dolium*** (Potonié 1931) Thomson & Pflug 1953

Pl. 7, figs 6, 12a, b

1931a *Pollenites dolium*; Potonié, pl. 1, fig. V45d (Germany, Ville, Beissels mine, Miocene).
1953 *Tricolporopollenites dolium* (Potonié 1931) n. comb.; Thomson & Pflug, p. 98, pl. 12, figs 112–117 (Germany, Brown coal from Frielendorf, Upper Oligocene to Lower Miocene).
1960 *Rhoipites dolium*; Potonié, p. 101.
1985 *Rhoipites dolium* (Potonié 1931) Potonié 1960; Zhu et al., p. 133, pl. 41, figs 2, 3; pl. 42, fig. 12 (Northwestern China, Chaidamu Basin, Oligocene to Miocene).
2000 *Tricolporopollenites dolium* (Potonié 1931) Thomson & Pflug 1953; Kohlman-Adamska & Ziembińska-Tworzydło, p. 52, 53, pl. 4, figs 1–5 (Central Poland, Neogene).

Size. 31×21 µm (n = 1)

Description. Tricolporate pollen grain in elliptic outline in equatorial view. The polar areas being narrowly rounded or slightly sharped. Colpi long, parallel, and almost reaching the poles. Pores large, elongated equatorially. Exine granulate. Surface sometimes with finely meridionally striate-reticulate ornament. The current study regards this as a collective species.

Stratigraphic occurrence. From Upper Oligocene to Lower Miocene in Germany (Thomson & Pflug 1953); several localities in China from Upper Eocene to Miocene (cf. Song et al. 1999); Neogene in Poland (Kohlman-Adamska & Ziembińska-Tworzydło 2000).

Occurrence in Shanwang. Rare.

Botanical affinity. Anacardiaceae, *Rhus* L. (Song et al. 1999), or Fagaceae (Kohlman-Adamska & Ziembińska-Tworzydło 2000).

(85) ***Tricolporopollenites edmundi*** (Potonié 1931) Thomson & Pflug 1953

Pl. 5, fig. 16

1931a *Pollenites edmundi* n. sp.; Potonié, p. 26, pl. 1, figs V53e, V52a, V53a (Germany, Ville, Miocene).

1952 *Poll. edmundi* Potonié; Meyer, p. 45, pl. III, fig. 47 (Germany, Wackersdorf, Miocene).
1953 *Tricolporopollenites edmundi* (Potonié 1931) n. comb.; Thomson & Pflug, p. 101, pl. 12, figs 126–131 (Germany, Brown coal from Emma Marxheim mine, Upper Oligocene; Brown coal from Rhine, Ville, Miocene).
1980 *Tricolporopollenites edmundi* (Potonié 1931) Thomson & Pflug 1953; Thiele-Pfeiffer, p. 151, pl. 12, figs 11–15 (Germany, Oder/Wackersdorf, Miocene).
1980 *Araliaceoipollenites baculatus* Song & Zheng n. sp.; Song et al., p. 11, pl. 3, fig. 21 (China, North Jiangsu Province, Eocene to Pliocene).
1994 *Araliaceoipollenites edmundi* (Potonié 1931) Potonié 1951 ex Potonié 1960; Ziembińska-Tworzydło et al., p. 38, pl. 12, figs 1–3 (Poland, Miocene).
1996 *Tricolporopollenites edmundi* (Potonié 1931) Thomson & Pflug 1953; Ashraf & Mosbrugger, p. 38, pl. 6, figs 14–19 (Germany, Lower Rhine Bay, Neogene).

Size. 35–40 × 38–42 µm, $\bar{x}$ = 38 × 40 µm (n = 3)

Description. Tricolporate pollen grains with obtuse rhombic outline in equatorial view, width is almost as long as length. Colpi thick-edged, strongly curved outwards in the equatorial plane, reaching and converging at the poles. Pores circular. Exine semitectate, ectexine thicker than endexine, reticulate. Reticula muri supported by 2–3 µm densely distributed bacula.

Stratigraphic occurrence. Frequent from Middle Oligocene to Miocene, rare in Pliocene (cf. Thiele-Pfeiffer 1980).

Occurrence in Shanwang. Rare. Only several specimens have been found in upper and middle part of the profile.

Botanical affinity. Uncertain. Probably an extinct genus from Mastixiaceae (Thiele-Pfeiffer 1980, Mohr 1984). Some authors also allocate this genus into the family Araliaceae or Cornaceae (Mamczar 1962).

(86) ***Tricolporopollenites marcodurensis*** Pflug & Thomson in Thomson & Pflug 1953

Type 1 after Bruch 1998

Pl. 6, fig. 1a–c

1953 *Tricolporopollenites marcodurensis* n. sp.; Pflug & Thomson in Thomson & Pflug, p. 103, pl. 13, figs 5, 6 (Germany, Rhine brown coal in Eschweiler, Miocene).
1980 *Tricolporopollenites marcodurensis* Thomson & Pflug 1953; Thiele-Pfeiffer, p. 157, pl. 13, figs 31–38 (Germany, Oder/Wackersdorf, Miocene).
1985 *Euphorbiacites marcodurensis* (Pflug & Thomson) Zheng; Song et al., p. 110, pl. 36, figs 26, 32, 33, 35–38 (China, Longjing Structural Area in the Shelf Basin of the East China Sea Region, Cenozoic).
1998 *Tricolporopollenites marcodurensis* Thomson & Pflug 1953 type 1; Bruch, p. 84, 85, pl. 12, figs 3, 4, 9 (Slovenia, Oligocene).

Size. 47 × 35 µm (n = 1)

Description. Tricolporate pollen grain in broadly elliptic outline in equatorial view. Colpi thick-edged, running subparallel, reaching the poles. Exopores equatorially elongated, endopores surrounded by colpi. Exine semitectate, reticulate. Lumina small, showing a slight and very gradual decrease towards the poles. For more detailed description see Bruch (1998).

Stratigraphic occurrence. Probably occurring in Upper Oligocene and abundant in Miocene and Pliocene in central and eastern Europe (Thiele-Pfeiffer 1980). Occurring in China during the Tertiary (Song et al. 1999).

Occurrence in Shanwang. Frequent but not numerous in the whole profile.

Botanical affinity. Vitaceae. According to Thiele-Pfeiffer (1980), it is similar to the pollen of *Ampelopsis* Michaux, *Cayratia* Juss. or *Parthenocissus* Planch.

(87) ***Tricolporopollenites marcodurensis*** Pflug & Thomson in Thomson & Pflug 1953

Type 2 after Bruch 1998

Pl. 5, fig. 17a–c

1980 *Tricolporopollenites marcodurensis* Thomson & Pflug 1953; Thiele-Pfeiffer, p. 157, pl. 13, figs 19–26 (Germany, Oder/Wackersdorf, Miocene).
1989 *Euphorbiacites wallensenensis* (Pflug) Li, Sung & Li 1978; Guan et al., p. 79, pl. 24, fig. 33 (China, Region around Bohai Sea, Miocene to Pliocene).
1998 *Tricolporopollenites marcodurensis* Thomson & Pflug 1953 type 2; Bruch, p. 86, pl. 12, figs 5, 6 (Slovenia, Oligocene).

Size. 35–43 × 24–32 µm, $\bar{x}$ = 40 × 29 µm (n = 3)

Description. Tricolporate pollen grains in slenderly elliptic outline in equatorial view. Colpi thick-edged, running subparallel, reaching the poles. Exopores circular, surrounded by colpi, endopores equatorially elongated. Exine semitectate, reticulate. Lumina small, showing a slight and very gradual decrease towards the poles. The complicated apertures have been regarded as typical *T. marcodurensis* structure. For more detailed description see Bruch (1998).

Stratigraphic occurrence. Probably occurring in Upper Oligocene and abundant in Miocene and Pliocene in central and eastern Europe (Thiele-Pfeiffer 1980). Occurring in China during Tertiary (Song et al. 1999).

Occurrence in Shanwang. Frequent but not numerous in the whole profile.

Botanical affinity. Vitaceae (Thiele-Pfeiffer 1980).

(88) ***Tricolporopollenites megaexactus*** (Potonié 1931) Thomson & Pflug 1953 ssp. ***exactus*** (Potonié 1931) Thomson & Pflug 1953

Pl. 5, fig. 11

1931a *Pollenites megaexactus* n. sp.; Potonié, p. 26, pl. 1, fig. V42b (Germany, Ville, Miocene).

1931a *Pollenites exactus* n. sp.; Potonié, p. 26, pl. 1, fig. V46b (Germany, Ville, Miocene).

1953 *Tricolporopollenites megaexactus* (Potonié 1931) n. comb. ssp. *exactus* (Potonié 1931) n. comb.; Thomson & Pflug, p. 101, pl. 12, figs 87–92 (Germany, different source localities, Eocene to Miocene).

1978 *Cyrillaceaepollenites megaexactus* (Potonié 1931) Potonié 1960; IPEDPMPI-NIGPAS, p. 112, pl. 36, figs 42, 43 (China, Coastal region of Bohai Sea, Early Tertiary).

1989 *Cyrillaceaepollenites megaexactus* (Potonié 1931) Potonié 1960; Guan et al., p. 80, pl. 24, figs 4–6, 16–24 (China, Region around Bohai Sea, Miocene to Pliocene).

1994 *Tricolporopollenites exactus* (Potonié 1931) Grabowska n. comb.; Ziembińska-Tworzydło et al., p. 28, pl. 16, figs 8–10 (Poland, Miocene).

1996 *Tricolporopollenites megaexactus* (Potonié 1931) Thomson & Pflug 1953 ssp. *exactus* (Potonié 1931) Thomson & Pflug 1953; Ashraf & Mosbrugger, p. 41, pl. 7, figs 1, 2 (Germany, Lower Rhine Bay, Neogene).

Size. 19×15 μm (n = 1)

Description. Small tricolporate pollen grain in oval outline in equatorial view. Long colpi reaching to the poles. Small pores slightly equatorially elongated. Exine psilate.

Stratigraphic occurrence. From Middle Eocene to Pliocene in central and eastern Europe (cf. Thiele-Pfeiffer 1980). In China during the Tertiary (Song et al. 1999).

Occurrence in Shanwang. Single specimen has been found in middle part of the profile.

Botanical affinity. Cyrillaceae, *Cliftonia* Banks, *Costaea* A. Rich, and *Cyrilla* Gard. (Potonié, Thomson & Thiergart 1950, Thomson & Pflug 1953, Ziembińska-Tworzydło 1974).

(89) ***Tricolporopollenites megaporatus*** Bruch 1998

Pl. 7, fig. 2a, b

1998 *Tricolporopollenites megaporatus* n. sp.; Bruch, p. 84, pl. 12, figs 1, 2 (Slovenia, Oligocene).

Size. 25–40×23–31 μm, $\bar{x}$ = 33×27 μm (n = 5)

Description. Tricolporate pollen grains in circular or slightly prolate circular outline in equatorial view. Colpi thick-edged, running parallel, almost reaching to the poles. Pores large, about 10 μm in diameter. Exine thick, ectexine is thicker than endexine, tectate. Tectum surface granulate, supported by densely distributed bacula.

Stratigraphic occurrence. Oligocene in Slovenia (Bruch 1998).

Occurrence in Shanwang. Sporadic.

Botanical affinity. Mastixiaceae (Bruch 1998).

(90) ***Tricolporopollenites pseudocingulum*** (Potonié 1931) Thomson & Pflug 1953

Pl. 4, fig. 13a–c; Pl. 7, figs 1a, b, 8a, b, 9a, b

1931b *Pollenites pseudocingulum* n. sp.; Potonié, p. 328–332, pl. 1, figs 2–4, 6, 19, 24, 26, 27 (Germany, Geiseltal, Eocene).

1953 *Tricolporopollenites pseudocingulum* (Potonié 1931) n. comb.; Thomson & Pflug, p. 99, pl. 12, figs 96–111 (Germany, different source localities, Eocene, Oligocene and Miocene).

1960 *Rhoipites pseudocingulum* (Potonié 1931); Potonié, p. 101, pl. 6, fig. 114.

1966 *Tricolporopollenites* sp. *striat-reticulate* Formen, f. 1; Sontag, p. 41, pl. 63, fig. 5a, b (Germany, Lower Lusatia, Miocene).

1978 *Rhoipites pseudocingulum* (Potonié 1931) Potonié 1960; IPEDPMPI-NIGPAS, p. 129, pl. 44, figs 5–9 (China, region around Bohai Sea, Early Tertiary).

1980 *Tricolporopollenites pseudocingulum* (Potonié 1931) Thomson & Pflug 1953; Thiele-Pfeiffer, p. 150, pl. 11, figs 52–54 (Germany, Oder/Wackersdorf, Miocene).

1996 *Tricolporopollenites pseudocingulum* (Potonié 1931) Thomson & Pflug 1953; Ashraf & Mosbrugger, p. 43, pl. 7, figs 7–9 (Germany, Lower Rhine Bay, Neogene).

2000 *Tricolporopollenites pseudocingulum* (Potonié 1931) Thomson & Pflug 1953; Kohlman-Adamska & Ziembińska-Tworzydło, p. 51, 52, pl. 2, figs 2–4; pl. 3, figs 1–5 (Central Poland, Neogene).

Size. 26–30×24–25 μm, $\bar{x}$ = 29×25 μm (n = 4)

Description. Tricolporate pollen grains in broadly elliptic outline, the polar areas slightly sharped. Colpi run and converge at the poles, strongly curved outwards in the equatorial plane. Pores elongated equatorially. Exine semitectate, surface finely meridionally striate-reticulate. According to Thiele-Pfeiffer (1980), this is a collective species group.

Stratigraphic occurrence. Occurring from Eocene, abundant in Oligocene and Miocene (Thomson & Pflug 1953, Mamczar 1962, Sontag 1966), Lower Tertiary in China (Song et al. 1999).

Occurrence in Shanwang. Rare.

Botanical affinity. Anacardiaceae, *Rhus* L. (Song et al. 1999), or Fagaceae (Kohlman-Adamska & Ziembińska-Tworzydło 2000).

(91) ***Tricolporopollenites wackersdorfensis*** Thiele-Pfeiffer 1980

Pl. 6, figs 6a, b, 7a, b

1952 *Poll. edmundi*?; Meyer, p. 45, pl. 3, fig. 45 (Germany, Wackersdorf, Miocene).
1956 *Pollenites* sp.; Meyer, p. 128, pl. 4, fig. 30 (Germany, Wackersdorf, Miocene).
1980 *Tricolporopollenites wackersdorfensis* n. sp.; Thiele-Pfeiffer, p. 153, pl. 12, figs 22–28 (Germany, Oder/Wackersdorf, Miocene).
1985 *Fupingopollenites wackersdorfensis* (Thiele-Pfeiffer 1980) n. gen. n. comb.; Liu, p. 64, 65, pl. 1, figs 5–7, 9–16 (China, Guangxi, Baise Basin, Middle to Late Oligocene).
1989 *Fupingopollenites wackersdorfensis* (Thiele-Pfeiffer 1980) Liu 1985; Guan et al., p. 110, pl. 39, figs 17–21 (China, Bohai coastal region, Miocene to Pliocene).
1994 *Tricolporopollenites wackersdorfensis* Thiele-Pfeiffer 1980; Ziembińska-Tworzydło et al., p. 40, pl. 16, fig. 35 (Poland, Miocene).

Size. 45–57 μm, $\bar{x} = 50$ μm (n = 5)

Description. Tricolporate pollen grains in triangular, roundly triangular outline in polar view, oblate to circular shape in equatorial view. Pores large round, only visible under certain polar or equatorial view. Colpi narrow, often sharply curved in equatorial plane. Exine semitectate, reticulate. Reticula muri supported by 2–3 μm densely distributed bacula. For more detailed description see Thiele-Pfeiffer (1980).

Stratigraphic occurrence. Eurasia, from Middle Eocene to Early Pleistocene (Song et al. 1999).

Occurrence in Shanwang. Frequent, especially abundant in the lower part of the profile.

Botanical affinity. Fabaceae, an extinct species from *Podocarpium* (Benth.) Yang & Huang (Liu et al. 2001).

(92) ***Tricolporopollenites* sp. 1**

Pl. 6, fig. 2

Size. 45×35 μm (n = 1)

Description. Tricolporate pollen grain in broadly elliptic outline in equatorial view. Polar areas are very rounded. Colpi long, thick-edged, almost reaching to the poles. Exine tectate, surface of tectum psilate.

Occurrence in Shanwang. Only one pollen grain has been found from the lower part of profile.

Botanical affinity. Unknown.

(93) ***Tricolporopollenites* sp. 2**

Pl. 6, fig. 8a, b

Size. 22×18 μm (n = 1)

Description. Tricolporate pollen grains in elliptic outline in equatorial view. Colpi thick-edged, curved outwards at equatorial plane, almost reaching to the poles. Pores slightly equatorially elongated. Exine about 2 μm thick, semitectate, reticulate.

Occurrence in Shanwang. Rare.

Botanical affinity. Unknown.

(94) ***Tricolporopollenites* sp. 3**

Pl. 6, fig. 9a, b

Size. 22×16 μm (n = 1)

Description. Tricolporate pollen grains in elliptic shape in equatorial view. Colpi thick-edged, running subparallel, not reaching to the poles. Pores large round. Exine about 1.5 μm thick, tectate, finely granulate.

Occurrence in Shanwang. Rare.

Botanical affinity. Unknown.

(95) ***Tricolporopollenites* sp. 4**

Pl. 6, fig. 10a, b

Size. 21 μm (n = 1)

Description. Tricolporate pollen grain in circular outline in equatorial view. Colpi narrow running parallel reaching to the poles.

Pores slightly meridionally elongated. Exine about 1 µm thick, semitectate, reticulate.

Occurrence in Shanwang. Rare.

Botanical affinity. Unknown.

(96) ***Tricolporopollenites* sp. 5**

Pl. 7, figs 4a, b, 5

Size. 20–24 µm, $\bar{x} = 22$ µm (n = 4)

Description. Tricolporate (or tricolporoidate) pollen grains in circular outline in equatorial view. Colpi slightly curved in equatorial plane, reaching and converging at the poles. Exine tectate, granulate.

Occurrence in Shanwang. Frequent but not numerous through the profile.

Botanical affinity. Unknown.

(97) ***Tricolporopollenites* sp. 6**

Pl. 7, figs 16, 17

Size. 23–30 µm, $\bar{x} = 25$ µm (n = 6)

Description. Tricolporate (or tricolpate) pollen grains in circular outline in polar view. Colpi thick-edged, almost reaching to the poles. Exine tectate, granulate.

Occurrence in Shanwang. Frequent but not present in large numbers.

Botanical affinity. Unknown.

(98) ***Tricolporopollenites* sp. 7**

Pl. 7, fig. 18a, b

Size. 28 µm (n = 1)

Description.Tricolporate pollen grain in circular outline in polar view. Colpi about 1/2 length to the poles. Pores are wider than colpi, with characteristical costae. Exine intectate, psilate. Surface irregularly reticulate.

Occurrence in Shanwang. Only a single specimen has been found in the upper part of the profile.

Botanical affinity. Unknown.

Genus ***Vitispollenites*** Thiele-Pfeiffer 1980

Type. *Vitispollenites tener* Thiele-Pfeiffer 1980

(99) ***Vitispollenites tener*** Thiele-Pfeiffer 1980

Pl. 4, fig. 15

1980 *Vitispollenites tener* n. gen. n. sp.; Thiele-Pfeiffer, p. 166, 167, pl. 16, figs 11–14 (Germany, Oder/Wackersdorf, Miocene).

1996 *Vitispollenites tener* Thiele-Pfeiffer 1980; Ashraf & Mosbrugger, p. 30, pl. 5, fig. 15 (Germany, Lower Rhine Bay, Neogene).

Size. 21×18 µm (n = 1)

Description. Small tricolporate pollen grain, oval outline in equatorial view. Pores small round. Colpi running parallel into the poles. Exine finely reticulate. For more detailed description see Thiele-Pfeiffer (1980).

Stratigraphic occurrence. Miocene of Germany, Wackersdorf and Lower Lusatia (Thiele-Pfeiffer 1980).

Occurrence in Shanwang. Sporadic throughout the whole profile.

Botanical affinity. Vitaceae, *Vitis* L. According to Thiele-Pfeiffer (1980), this pollen form can not be allocated to an exact recent *Vitis* species.

Tricolporate (E:P < 1) pollen grains

Genus ***Hemitrapapollenites*** Liu 1986

Type. *Hemitrapapollenites medius* (Guan 1985) Liu 1986

(100) ***Hemitrapapollenites medius*** (Guan 1985) Liu 1986

Pl. 10, fig. 15

1985 *Sporotrapoidites medius* Guan n. sp.; Song et al., p. 120, 121, pl. 40, figs 24, 25; pl. 42, figs 5, 6; pl. 55, figs 36, 37 (China, Longjing Structural Area in the Shelf Basin of the East China Sea Region, Tertiary).

1986 *Hemitrapapollenites medius* (Guan 1985) n. gen. n. comb.; Liu, p. 75, pl. III, figs 15, 16, 21, 22, 28 (China, Shandong Shanwang, Yaoshan Formation, Miocene).

Size. 30 µm (n = 1)

Description. Tricolporate pollen grain in triangular outline in polar view. Colpi obscure. Ectexine thickening, forming prominent ridges along areas between pores and poles. The ridges do not connect with each other at the poles but form a triangle in polar area. Exine tectate, granulate.

Stratigraphic occurrence. Neogene in eastern China and Japan (Liu 1986).

Occurrence in Shanwang. Only a single specimen has been found in upper part of the profile.

Botanical affinity. Uncertain. Probably it relates to family Hydrocaryaceae or Trapellaceae (Liu 1986).

Genus *Intratriporopollenites* Pflug & Thomson in Thomson & Pflug 1953 emend. Mai 1961

Type. *Intratriporopollenites instructus* (Potonié 1931) Thomson & Pflug 1953

(101) *Intratriporopollenites instructus* (Potonié 1931) Thomson & Pflug 1953

Pl. 10, figs 9, 10

1931c *Tiliae-pollenites instructus* n. sp.; Potonié, p. 556, fig. 9 (Germany, Lusatia, Miocene).
1953 *Intratriporopollenites instructus* (Potonié & Venitz 1934) n. comb.; Thomson & Pflug, p. 89, pl. 10, figs 16, 18–22 (Germany, Ville, Miocene; Wallensen, Pliocene).
1961 *Intratriporopollenites instructus* (Potonié 1931) Thomson & Pflug 1953 ssp. *instructus*; Mai, p. 66, pl. 12, figs 1–18 (Germany Muskau, Miocene).
1978 *Tiliaepollenites instructus* (Potonié 1931) Potonié 1960; IPEDPMPI-NIGPAS, p. 126, pl. 46, figs 32–35 (China, Coastal region of Bohai Sea, Early Tertiary).
1980 *Intratriporopollenites instructus* (Potonié 1931) Thomson & Pflug 1953; Thiele-Pfeiffer, p. 131, pl. 9, figs 1, 2 (Germany, Wackersdorf, Miocene).
1989 *Tiliaepollenites instructus* (Potonié 1931) Potonié 1960; Guan et al., p. 105, pl. 37, figs 20–25 (China, Region around Bohai Sea, Miocene to Pliocene).
1994 *Intratriporopollenites instructus* (Potonié 1931) Thomson & Pflug 1953; Ziembińska-Tworzydło et al., p. 41, pl. 17, figs 20, 21 (Poland, Neogene).

Size. 33–42 µm, $\bar{x} = 37$ µm (n = 4)

Description. Tricolporate pollen grains in rounded-triangular outline in polar view. Colpi short. Pores situated between the angles in equatorial plane, endexine around pores thickening and forming annuli. Annuli round shape. Exine tectate, surface of tectum reticulate-foveolate. For more detailed description see Mai (1961).

Stratigraphic occurrence. From Upper Oligocene to Lower Pliocene (Mai 1961); Tertiary in China (Song et al. 1999).

Occurrence in Shanwang. Frequent but not in large numbers.

Botanical affinity. Tiliaceae, *Tilia* L. (Thomson & Pflug 1953).

(102) *Intratriporopollenites pseudoinstructus* Mai 1961

Pl. 10, fig. 5a, b

1961 *Intratriporopollenites pseudoinstructus* n. sp.; Mai, p. 65, pl. 10, figs 32–34 (Germany, Lower Eocene).
1986 *Tiliaepollenites* cf. *insculptus* (Mai); Liu, pl. 3, fig. 38 (China, Shandong Shanwang, Yaoshan Formation, Miocene).

Size. 30 µm (n = 1)

Description. Tricolporate pollen grains with triangular outline in polar view. Colpi short. Pores situated between the angles in equatorial plane, endexine around pores thickening and forming annuli. Annuli in rounded-triangular outline, somehow following the colpi. Exine tectate, surface of tectum reticulate-foveolate. For detailed description see Mai (1961).

Stratigraphic occurrence. Upper Palaeocene to Lower Oligocene (Mai 1961).

Occurrence in Shanwang. Rare.

Botanical affinity. Tiliaceae (Mai 1961).

Genus *Lonicerapollis* Krutzsch 1962

Type. *Lonicerapollis gallwitzii* Krutzsch 1962

(103) *Lonicerapollis gallwitzii* Krutzsch 1962

Pl. 10, fig. 11

1962 *Lonicerapollis gallwitzii* n. fsp.; Krutzsch, p. 275, pl. V, figs 1–6 (Germany, Lusatia, Welzow, Lower Miocene).
1980 *Lonicerapollis* cf. *gallwitzii* Krutzsch 1962; Thiele-Pfeiffer, p. 138, pl. 10, figs 23–25 (Germany, Oder/Wackersdorf, Miocene).
1989 *Lonicerapollis gallwitzii* Krutzsch 1962; Guan et al., p. 68, pl. 21, figs 15–20 (China, Region around Bohai Sea, Miocene to Pliocene).
1996 *Lonicerapollis gallwitzii* Krutzsch 1962; Ashraf & Mosbrugger, p. 59, pl. 9, fig. 4 (Germany, Lower Rhine Bay, Neogene).

Size. 53–70 µm, $\bar{x} = 59$ µm (n = 3)

Description. Large pollen grains in rounded-triangular outline in polar view. Colpus short and narrow, situated at the corner of the triangle in the equatorial plane. Curved ridge crossing the end of the colpus. Exine tectate, tectum supported by densely distributed bacula. Long echinae widely spaced on the surface.

Stratigraphic occurrence. From Middle Oligocene to Pliocene (Krutzsch 1962). Several localities in China during Tertiary (cf. Song et al. 1999).

Occurrence in Shanwang. Sporadic through the profile.

Botanical affinity. Caprifoliaceae, *Lonicera* L. (Krutzsch 1962), or *Triosteum* L. (Thiele-Pfeiffer 1980).

Genus ***Sapindaceidites*** Wang ex Sun & Zhang 1979

Type. *Sapindaceidites asper* Wang ex Sun & Zhang 1979

(104) ***Sapindaceidites concavus*** Wang 1978

Pl. 10, fig. 14

1978 *Sapindaceidites concavus* Wang n. sp.; IPEDPMPI-NIGPAS, p. 133, pl. 45, figs 10–12 (China, Bohai coastal region, Early Tertiary).
1980 *Boehlensipollis* Group A; Wilkinson & Boulter, p. 65, 66, pl. 10, figs 21–25 (British Isles, Oligocene).

Size. 20 µm (n = 1)

Description. Small tricolporate pollen grain in deeply concave-triangular outline in polar view. Colpi straight, long, meeting at the poles. Pores situated at the corners of the triangle in equatorial plane, protruding. Endexine absent around pore region, forming hemicycle-shaped atrium. Exine tectate, psilate.

Stratigraphic occurrence. Oligocene in British Isles (Wilkinson & Boulter 1980); From several localities in China during Tertiary, mostly from Early Tertiary (Song et al. 1999).

Occurrence in Shanwang. Only a single specimen has been encountered from middle part of the profile.

Botanical affinity. Sapindaceae (Song et al. 1999).

Genus ***Slowakipollis*** Krutzsch 1962

Type. *Slowakipollis cechovici* (Pacltová 1958) Krutzsch 1962

(105) ***Slowakipollis cechovici*** (Pacltová 1958) Krutzsch 1962

Pl. 10, fig. 13

1958 *Porocolpopollenites cechovici* n. sp.; Pacltová, p. 296, 298, pl. 12, figs 5, 6 (Czech Republic, Handlova, Upper Miocene).
1962 *Slowakipollis cechovici* (Pacltová 1958) n. comb; Krutzsch, p. 273, pl. 4, figs 24–26 (Germany, Hessen, Middle to Upper Miocene).

Size. 35 µm (n = 1)

Description. Tricolporate pollen grain in triangular outline in polar view. Colpi short, narrow. Pores equatorially elongated, situated at the corners of the triangle in equatorial plane. Exine tectate, granulate.

Stratigraphic occurrence. Middle to Upper Miocene (Pacltová 1958, Krutzsch 1962).

Occurrence in Shanwang. Only a single specimen has been encountered from the upper part of the profile.

Botanical affinity. Elaeagnaceae (Krutzsch 1962, Planderová 1972).

(106) ***Slowakipollis elaeagnoides*** Krutzsch 1962

Pl. 10, fig. 12

1962 *Slowakipollis elaeagnoides* n. sp.; Krutzsch, p. 274, pl. IV, figs 16–23 (Germany, Lower Miocene).
1972 *Slowakipollis* cf. *cechovici* (Pacltová 1958) Krutzsch 1962 and *Slowakipollis klausii* n. sp.; Planderová, p. 250, pl. 32, figs 7–9; pl. 33, figs 7–9 (Slovakia, West Carpathians Mountains, Pliocene).
1973 *Slowakipollenites elaeagnoides* Krutzsch 1962; Nagy, pl. 5, figs 2, 4 (Hungary, Cserehát; Tortonian, Upper Miocene).
1978 *Elaeagnacites laevigatus* Ke & Shi n. gen. n. sp.; IPEDPMPI-NIGPAS, p. 131, pl. 45, fig. 6 (China, Coastal region of Bohai Sea, Early Tertiary).
1980 *Slowakipollis elaeagnoides* Krutzsch 1962; Thiele-Pfeiffer, p. 137, pl. 9, fig. 31 (Germany, Oder/Wackersdorf, Miocene).
1984 *Slowakipollis elaeagnoides* Krutzsch 1962; Mohr, p. 85, pl. 14, fig. 10 (Germany, North Rhine Bay, Frechen, Fortuna Garsdorfe, from Miocene to Pliocene).
1989 *Elaeagnacites huanghuaensis* Ke & Shi 1978; Guan et al., p. 78, pl. 24, figs 31, 32 (China, Region around Bohai Sea, Miocene to Pliocene).
1994 *Slowakipollis elaeagnoides* Krutzsch 1962; Ziembińska-Tworzydło et al., p. 41, pl.17, figs 14, 15 (Poland, Neogene).
1996 *Slowakipollis elaeagnoides* Krutzsch 1962; Ashraf & Mosbrugger, p. 67, pl. 10, fig. 5 (Germany, Lower Rhine Bay, Neogene).

Size. 35 µm (n = 1)

Description. Tricolporate pollen grain in convex-triangular outline in polar view. Colpi short, narrow. Pores situated at the corners of the triangle in equatorial plane, protruding beyond the equatorial outline. Endexine around pore absent, forming atrium. Exine tectate, psilate.

Stratigraphic occurrence. From Lower Miocene to Pliocene in central Europe (Thiele-Pfeiffer 1980), and several localities in China during the Tertiary.

Occurrence in Shanwang. Only a single pollen grain has been found from upper part of the profile.

Botanical affinity. Elaeagnaceae (Krutzsch 1962).

Genus *Tubulifloridites* Cookson 1947 ex Potonié 1960

Type. *Tubulifloridites antipodica* (Cookson 1947) Potonié 1960

(107) *Tubulifloridites granulosus* Nagy 1969

PL. 6, fig. 3a–c

1967 *Tricolporopollenites microechinatus* n. fsp.; Trevisan, p. 47, pl. 32, figs 1–4 (Italy, Gabbro, Upper Miocene).
1969 *Tubulifloridites granulosus* n. sp., Nagy; p. 206 (438), pl. 49, figs 3, 4 (Hungary, Mecsek Mountains, Miocene).
1980 *Tricolporopollenites microechinatus* Trevisan 1967; Thiele-Pfeiffer, p. 159, pl. 14, figs 12–14 (Germany, Oder/Wackersdorf, Miocene).
1984 *Tubulifloridites granulosus* Nagy 1969; Mohr, p. 92, pl. 17, figs 6.1, 6.2 (Germany, North Rhine Bay, Frechen, Upper Miocene).
1985 *Echitricolporites blumeaformis* Zheng n. sp.; Song et al., p. 103, 104, pl. 34, fig. 20 (China, Longjing Structural Area in the Shelf Basin of the East China Sea Region, Pliocene).
1989 *Echitricolporites blumeaformis* Zheng 1985; Guan et al., p. 74, pl. 23, fig. 4 (China, Region around Bohai Sea, Miocene to Pliocene).

Size. 28 µm (n = 1)

Description. Tricolporate pollen grain in circular outline in polar view. Each mesocolpium (mesoporium) with 5–6 spines in polar view. Spines about 3–4 µm long. Exine tectate, echinate.

Stratigraphic occurrence. As collective species, from Upper Oligocene to Pliocene in Europe (cf. Thiele-Pfeiffer 1980). Several localities in China from Miocene to Pleistocene (cf. Song et al. 1999).

Occurrence in Shanwang. Single specimen has been found in the middle part of the profile.

Botanical affinity. Asteraceae (Compositae), sub-family Asteroideae, Tubuliflorae (Nagy 1969).

Polycolpate pollen grains

Genus *Lymingtonia* Erdtman 1960

Type. *Lymingtonia rhetor* Erdtman 1960

(108) *Lymingtonia rhetor* Erdtman 1960

Pl. 12, fig. 9a, b

1960 *Lymingtonia rhetor* n. sp.; Erdtman, p. 48, pl. 2, figs a–c (England, Berkshire, Upper Eocene).

Size. 33 µm (n = 1)

Description. Pantocolpate pollen grain in circular outline. Exine about 3–4 µm thick, tectate, punctate. Columellae densely distributed under the tectum.

Stratigraphic occurrence. Upper Eocene from Berkshire, England (Erdtman 1960), and current Miocene material from Shanwang, China.

Occurrence in Shanwang. Only one specimen has been encountered in the upper part of the profile.

Botanical affinity. Nyctaginaceae (Erdtman 1960).

STRATIGRAPHY

The age of the Shanwang biotic assemblage has been previously determined from both palaeontological data (e.g. Young 1936, Chaney & Hu 1940, Song 1959, Li 1981) and radiometric data (e.g. Wang et al. 1981, Chen & Peng 1985, Jin 1985, Zhu M. et al. 1985). These different approaches have provided a diversity of age ranges, and in some cases these data present conflicting results (Tab. 3).

According to mammalian fossils, palaeozoological dates have been assigned to the MN4 or MN5 biozones that are of late Early Miocene or early Middle Miocene age. The radiometric age produced by Wang et al. (1981) of 44.1 ± 4 Ma – 20.0 ± 2/24.0 ± 1.2 Ma is inconsistent with all other results from both radiometric and palaeontological dating, giving an age range from Eocene to Early Miocene for the Shanwang biota. In contrast, the three subsequent radiometric analyses

Table 3. Chronologies of the Shanwang Basin from several sources

Data type	Section or zone	Age	Source
Vertebrate fossils	Fossiliferous section of the Shanwang Formation	Late Miocene (Miocene divided in 2 periods)	Young (1936)
Fossil leaves	Fossiliferous section of the Shanwang Formation	Late Miocene Sarmatian stage of Europe or Mascall to San Pablo of North America	Chaney & Hu (1940)
Palynology	Fossiliferous section of the Shanwang Formation	Middle to Late Miocene	Song (1959)
Fossil leaves	Fossiliferous section of the Shanwang Formation	Middle Miocene	Li (1981)
Mammalian fossils	Fossiliferous section of the Shanwang Formation	Middle Miocene	Wu & Chen (1978)
Mammalian fossils	Fossiliferous section of the Shanwang Formation	MN4 or MN5	Qiu et al. (1985)
Micromammals	Fossiliferous section of the Shanwang Formation	MN5	Qiu & Sun (1988)
Mammalian fossils	Fossiliferous section of the Shanwang Formation	Early Middle Miocene	Yan et al. (1983) Qiu (1990)
Potassium-Argon data	Basalts below and above the fossiliferous section of the Shanwang Formation	44.1 ± 4 Ma – 20.0 ± 2 – 24.0 ± 1.2 Ma	Wang et al. (1981)
Potassium-Argon data	Basalts from the Niushan Formation and the Yaoshan Formation	16.78 ± 0.13 Ma – 9.66 ± 0.15Ma	Zhu et al. (1985)
Potassium-Argon data	Basalts from the Niushan Formation and the Yaoshan Fromation	18.87 ± 0.49 Ma – 10.64 ± 0.28 Ma	Chen & Peng (1985)
Potassium-Argon data	Basalts below and above the fossiliferous section	18.18 ± 0.79 Ma – 14.11 ± 0.66 Ma	Jin (1985)

using Potassium-Argon dates by Chen & Peng (1985), Jin (1985) and Zhu M. et al. (1985) provide more consistent results, although with diverse ranges varying from 18.87–9.66 Ma. Of this total range, the three sets of results overlap between 16.78 and 14.11 Ma, as shown in Fig. 8. Based on these Potassium-Argon data, the Shanwang fossil biota is considered most likely to have formed during this interval and between 16.78 to 14.11 Ma. According to Rögl's (1996) standard geological time scale for the Cenozoic, the Early Miocene is from 23.8 Ma to 16.4 Ma, the Middle Miocene is from 16.4 Ma to 11.0 Ma, and the Late Miocene from 11.0 Ma to 5.3 Ma. As such, the radiometric dates produced by Chen & Peng (1985), Jin (1985) and Zhu M. et al. (1985) indicate that the Shanwang biota is of Middle Miocene age, occurring between the Langhian and the early Serravallian.

The total 90 sporomorph taxa identified from the Shanwang palynoassemblage have previously known stratigraphic ranges within the Tertiary. As indicated in Table 4, the majority of these taxa have wide stratigraphical ranges with only 9 taxa restricted to the Miocene. Thus the sporomorphs add no more information on the age of the Shanwang biotic assemblage.

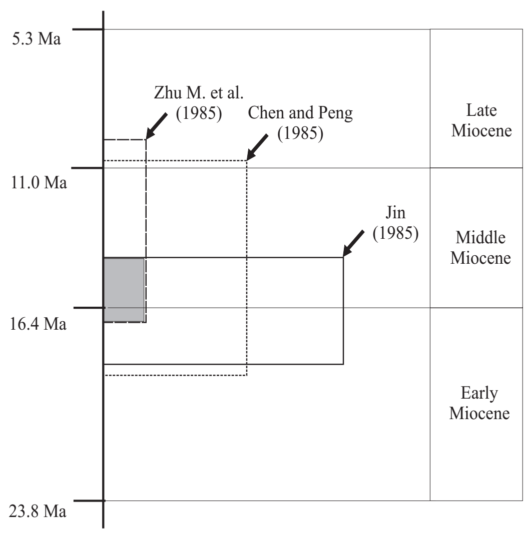

Fig. 8. Ranges of Potassium/Argon ages given for the Shanwang biota

Table 4. Previously known stratigraphical ranges of the Shanwang Miocene palynomorphs

Palynomorph taxa	Eocene			Oligocene		Miocene			Pliocene		Pleistocene
	L	M	U	L	U	L	M	U	L	U	
Laevigatosporites haardti											
Pityosporites div.sp.											
Abiespollenites div.sp.											
Piceapollis div.sp.											
Alnipollenites verus											
Ulmipollenites undulosus											
Zelkovaepollenites potoniei											
Zelkovaepollenites thiergartii											
Celtipollenites komloensis											
Quercopollenites robur											
Quercopollenites granulate											
Quercopollenites petrea											
Sequoiapollenites largus											
Ephedripites (*Distachyapites*) *cheganicus*											
Sapindaceidites concavus											
Inaperturopollenites concedipites											
Momipites punctatus											
Aceripollenites striatus											
Tricolporopollenites cingulum oviformis											
Nyssapollenites kruschi accessorius											
Nyssapollenites kruschi analepticus											
Triatriopollenties bituitus											
Eucommiaceoipollenites eucommides											
Tricolpopollenites microhenrici											
Oleoidearumpollenites microreticulatus											
Caryapollenites simplex											
Operculumpollis operculatus											
Periporopollenites formosanaeformis											
Periporopollenites orientaliformis											
Periporopollenites styracifluaeformis											
Ilexpollenites propinquus											
Tricolporopollenites dolium											
Tricolporopollenites pseudocingulum											
Engelhardtioidites microcoryphaeus											
Intratriporopollenites pseudinstructus											
Ehpedripites (*Distachyapites*) *fushunensis*											
Pterocaryapollenites stellatus											
Verrucatosporites favus											
Zonalapollenites maximus											
Tricolporopollenites megaexactus											
Celtipollenites intrastructurus											
Sciadopityspollenites serratus											
Ephedripites (*Distachyapites*) *fusiformis*											
Lymingtonia rhetor											
Tricolpopollenites henrici											
Carpinipites carpinoides											
Nyssapollenites kruschi rodderensis											
Chenopodipollis maximus											
Polypodiaceoisporites gracillimus											
Laevigatosporites gracilis											
Tricolporopollenites edmundi											
Zonalapollenites igniculus											
Trivestibulopollenites betuloides											
Chenopodipollis multiplex											
Lonicerapollis gallwitzii											
Intratriporopollenites instructus											
Graminidites gramineoides											
Zonalapollenites spinosus											
Faguspollenites verus											
Ephedripites (*Ephedripites*) *wolkenbergensis*											
Tubulifloridites granulosus											
Punctioratipollis ludwigi											
Tricolporopollenites marcodurensis type 1											
Tricolporopollenites marcodurensis type 2											
Artemisiaepollenites sellularis											
Persicarioipollis franconicus											
Persicarioipollis welzowense											
Tricolporopollenites wackersdorfensis											
Tricolpopollenites asper											
Rhoipites striatus											
Tricolpopollenites minimireticulatus											
Triporopollenites rhenanus											
Slowakipollis elaeagnoides											
Zelkovaepollenites verrucatus											
Oleoidearumpollenites reticulatus											
Alangiopollis barghoornianum											
Juglandipollis juglandoides											
Tricolpopollenites minimireticulatus											
Hemitrapapollenites medius											
Tricolpopollenites cf. *sinuosimuratus*											
Arecipites convexus											
Rhuspollenites ornatus											
Faguspollenites crassus											
Faguspollenites gemmatus											
Faguspollenites subtilis											
Vitispollenites tener											
Graminidites micropunctatus											
Slowakipollis cechovici											
Graminidites pseudogramineus											
Zonalapollenites minispinus											

PALAEOECOLOGY

FLORISTICS AND PLANT COMPOSITION

The overall composition of the Shanwang palynoflora is rich in deciduous broad-leaved elements and conifers of which the majority of the genera present are extant. The palynoflora is dominated by diverse associations of members of the Juglandaceae (*Carya*, *Engelhardia*, *Juglans*, *Pterocarya*,), Fagaceae (*Fagus*, *Quercus*, *Castanea*), Ulmaceae (*Celtis*, *Ulmus*, *Zelkova*,), Betulaceae (*Alnus*, *Betula*, *Carpinus*), Altingiaceae (*Liquidambar*), Tiliaceae (*Tilia*), Aceraceae (*Acer*) and the Eucommiaceae (*Eucommia*). Herbaceous plants such as the Poaceae (Gramineae) and Chenopodiaceae are comparatively sparse in this palynoflora. Conifers are represented by members of the Pinaceae (*Abies*, *Picea*, *Pinus*, and *Tsuga*) which represent the main taxonomic divisions from mountain coniferous forests, and also a few members of the Taxodiaceae including *Taxodium*. Ferns are rare in the palynoflora and include several species from the families Polypodiaceae and Pteridaceae that are presently distributed in tropic to sub-tropic areas of the world.

The majority of these elements such as *Acer*, *Alnus*, *Betula*, *Carpinus*, *Castanea*, *Fagus*, *Juglans*, *Quercus*, *Tilia*, and *Ulmus* belong to the “North Temperate” forest floras that are presently distributed in the temperate areas of Europe, Asia and North America. Some of these taxa extend southwards into tropical areas, such as *Fagus* that in China is mainly distributed in subtropical areas although its distribution is centred in north temperate areas. *Carya*, *Engelhardia*, *Liquidambar*, *Nyssa*, *Tsuga*, and are representatives of the “Eastern Asia–North America composition” forest floras that have disjunct distributions in temperate and subtropical areas of eastern Asia and North America. In China, these taxa are the major tree elements in the subtropical forests. *Celtis* and *Ilex* are the “tropical components” of forest floras, but can be distributed in temperate areas as well as tropical regions. The distribution of *Eucommia* is limited to eastern Asia and is known especially from the Chinese mainland. Some elements of the palynoflora such as *Pterocarya* and *Zelkova* can extend as far west as the Near East, Caucasus, and the Mediterranean area.

Wang (1961) divided the modern Chinese deciduous forests into 4 types. According to this division, the floristic composition of the Shanwang Miocene flora was very similar to the “mixed mesophytic forest” type that is transitional between the warm-temperate broad-leaved deciduous type typical of northern China and the subtropical evergreen broad-leaved type typical of southern China. This floral type extends at present over a long distance from the lower Chang Jiang (Yangze) river on the west Pacific coast to the middle Chang Jiang (Yangze) river areas of Sichuan Province. In China this is the most diverse kind of deciduous forest in which the composition varies among all the deciduous elements, particularly the large families such as Juglandaceae, Betulaceae, Fagaceae, Ulmaceae, Altingiaceae, Rosaceae, Aceraceae, and Ericaceae.

SPOROMORPH DISTRIBUTION WITHIN THE SHANWANG PROFILE

Most of the sporomorphs are distributed more or less evenly throughout the 18 layers. Layer 19 contains almost no palynological data and has not been included in this part of the study for this reason. Only a few intervals show some minor variation and are notable follows (Fig. 9).

In layer 2 from 22.05–21.25 m, *Zelkovaepollenites potoniei* percentages range between 6.4% and 55.28%, *Zelkovaepollenites thiergartii* percentages range between 0.85% and 14.63%, with both reaching their maximum percentages.

In layer 3 from 21.25–19.45 m, the percentages of *Tricolporopollenites wackersdorfensis* increase abruptly to 27.69% and reach its maximum percentage of 32.33%. *Periporopollenites formosanaeformis* and *Periporopollenites orientalisformis* drop abruptly to their lowest percentages ranging from 0 to 1.55% and 0 to 1.98% respectively.

In layer 9 from 10.75–9.25 m, *Faguspollenites* and *Alnuspollenites* pollen increase abruptly with *Faguspollenites* percentages averaging 14% and, reaching its peak percentage of 24.80%; while *Alnuspollenites* percentages average approximately 6.0% and, reaching its peak percentage of 16.73%. From this layer *Nyssapollenites* pollen begin to appear frequently although in low percentages (typically around 0.9%).

In layer 13 from 7.9–7.2 m, the percentages of *Eucommiaceoipollenites eucommides* increase abruptly, average around 8%, reach their maximum of 14.74%.

Layer 18 from 3.3–1.8 m is dominated by increased *Ulmipollenites undulosus* (34%) and *Zelkovaepollenites* (around 25%).

The most interesting variation is layer 3, which is a mudstone, sandstone and diatomite unit (Fig. 5), *Periporopollenites* (*Liquidambar*) percentages drop abruptly to their lowest levels. In the same unit the percentages of *Tricolporopollenites wackersdorfensis* which is an extinct species of the genus *Podocarpium* (Liu et al. 2001) increase abruptly attaining their highest percentages. A similar situation occurs within layer 6 which is a layer dominated by diatomaceous shales with intercalated mudstone horizons. In this layer, *Periporopollenites* (*Liquidambar*) values drop to their second lowest values and again the values of *Trocolporopollenites wackersdorfensis* increase, attaining their second highest percentages. In layer 6 the percentages of *Chenopodipollis multiplex* (Chenopodiaceae/Amaranthaceae) which may indicate dry habitats increase abruptly and reach a maximum of 7.54% at the same time (Fig. 9). Considering *Periporopollenites* (*Liquidambar*) lives in riparian or floodplain environments and knowing that this plant requires habitats with humid soils ecologies (e.g. Kuprianova 1960, Mai 1978, Van der Burgh 1987), it might be argued that *Tricolporopollenites wackersdorfensis* had lived in a comparably dry soil environment.

CLUSTER ANALYSIS

The result of the analysis is shown as a dendrogram in Fig. 10. At the level of similarity of 2.3, the dendrogram subdivides the Shanwang Miocene palynological assemblages into four clusters, which are designated as A, B, C and D respectively. Each cluster is interpreted as vegetation using the ecological information from nearest living relatives of its dominant taxa that are shown in Tab. 5.

Cluster A: The most abundant taxon in this cluster is *Fagus*, accompanying with taxa *Alnus*, *Castanea*, *Betula*, *Quercus*, *Nyssa*, *Engelhardia*, and *Myrica* (refer to Fig. 9). This cluster is predominantly distributed in the upper part of the profile (Fig. 11). Ecologically this cluster suggests an upland *Fagus* forest with well-drained habitat ecology, and intermingled with some elements from swamp forests, such as *Alnus* and *Nyssa*.

Cluster B: This is dominated by the taxa *Liquidambar* and *Pterocarya*, accompanying with taxa *Eucommia*, *Tsuga*, *Tilia*, and Vitaceae (refer to Fig. 9). This cluster is nearly evenly distributed throughout the whole profile showing only lower amounts in the lower (layer 3) and upper (layer 18) parts (Fig. 11). Ecologically this can be interpreted as *Liquidambar*-*Pterocarya* riparian forest.

Cluster C: This is dominated by *Zelkova*, *Ulmus*, *Celtis*, members of the Ulmaceae family, *Tricolporopollenites wackersdorfensis* and a small amount of accompanying herbaceous taxa such as Chenopodiaceae, Poaceae (Gramineae), *Polygonum*, with *Ephedra*, and the fern

Table 5. Palynological cluster, abundant taxa as well as possible vegetation types of Shanwang Miocene

Palynological cluster	Abundant taxa and their ecological demands	Possible vegetation types
Cluster A	*Fagus* upland *Fagus* forest from well-drained environment, accompanyed by *Alnus*, *Castanea*, *Betula*, *Quercus*, *Nyssa*, *Engelhardia*, and *Myrica*	Upland *Fagus* forest from well-drained environment, mixed with swamp element
Cluster B	*Liquidambar*, *Pterocarya* riparian forest accompanyed by *Eucommia*, *Tsuga*, *Tilia*, and Vitaceae	*Liquidambar* – *Pterocarya* riparian forest
Cluster C	*Zelkova*, *Ulmus*, *Celtis* riparian forest from more calcareous environment intermixed with *Tricolporopollenites wackersdorfensis* (extinct Fabaceae probably from dry environment) and Chenopodiaceae, Poaceae (Gramineae), *Polygonum*, *Ephedra*, Polypodiaceae	*Zelkova* – *Ulmus* riparian forest from more calcareous environment, mixed with dry element
Cluster D	*Carya*, riparian forest, wet mixed mesophytic forest *Quercus*, *Juglans*, mixed mesophytic forest *Carpinus*, mixed mesophytic forest accompanyed by *Acer*, Poaceae (Gramineae), *Ephedra*, and Pteridaceae	Mixed mesophytic forest

Fig. 9 (wklejka) (po stronie 52)

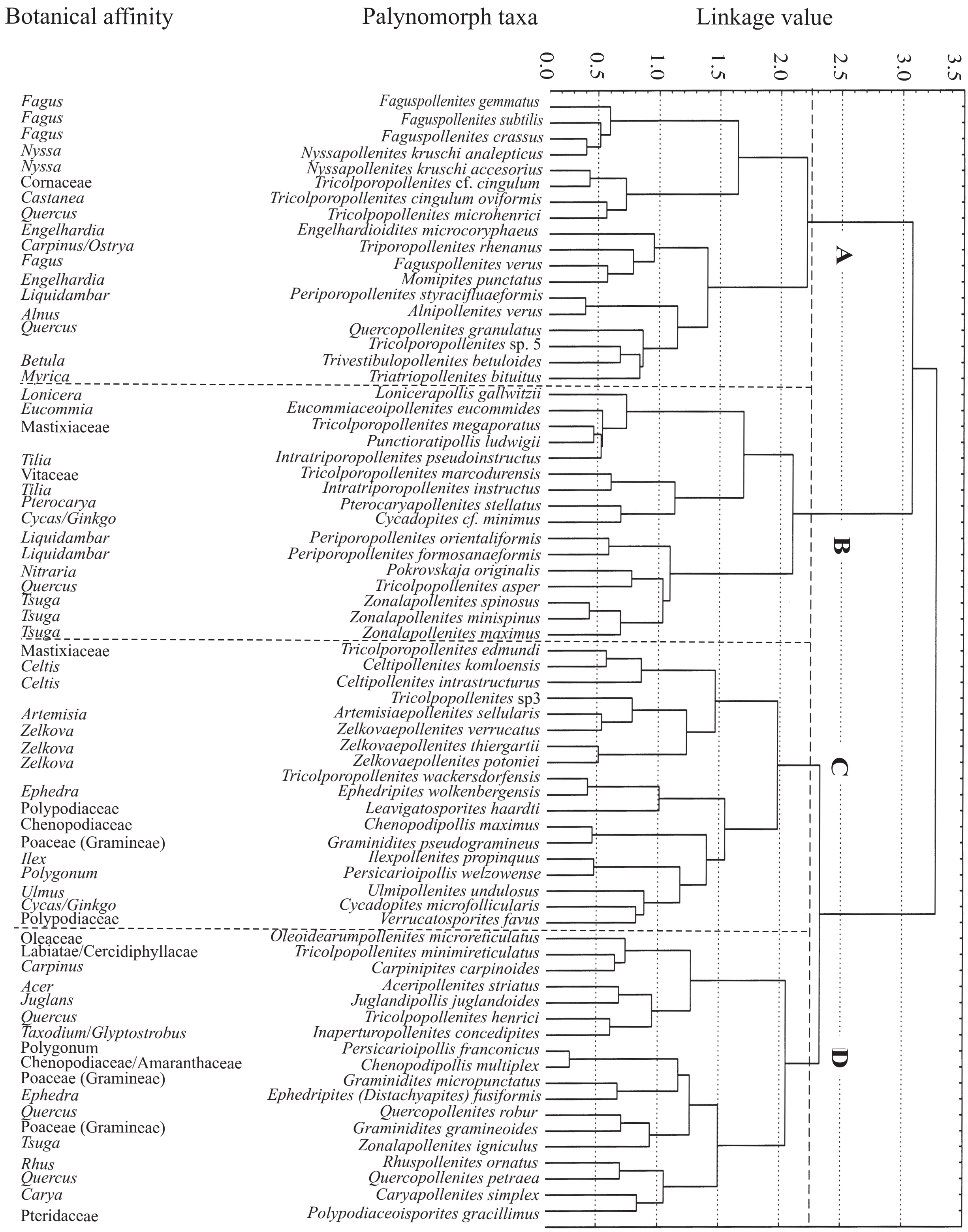

Fig. 10. Cluster analysis of sporomorph taxa

family Polypodiaceae (refer to Fig. 9). This cluster appears at intervals throughout the whole profile but increases in the lower (layer 1, 2 and 3) and upper (layer 18) parts of the profile (Fig. 11). This cluster can be considered as an *Ulmus-Zelkova* riparian forest, which might belong to more calcareous environments (Boulter et al. 1993), intermixed with *Tricolporopollenites wackersdorfensis* which may be from a drier habitat.

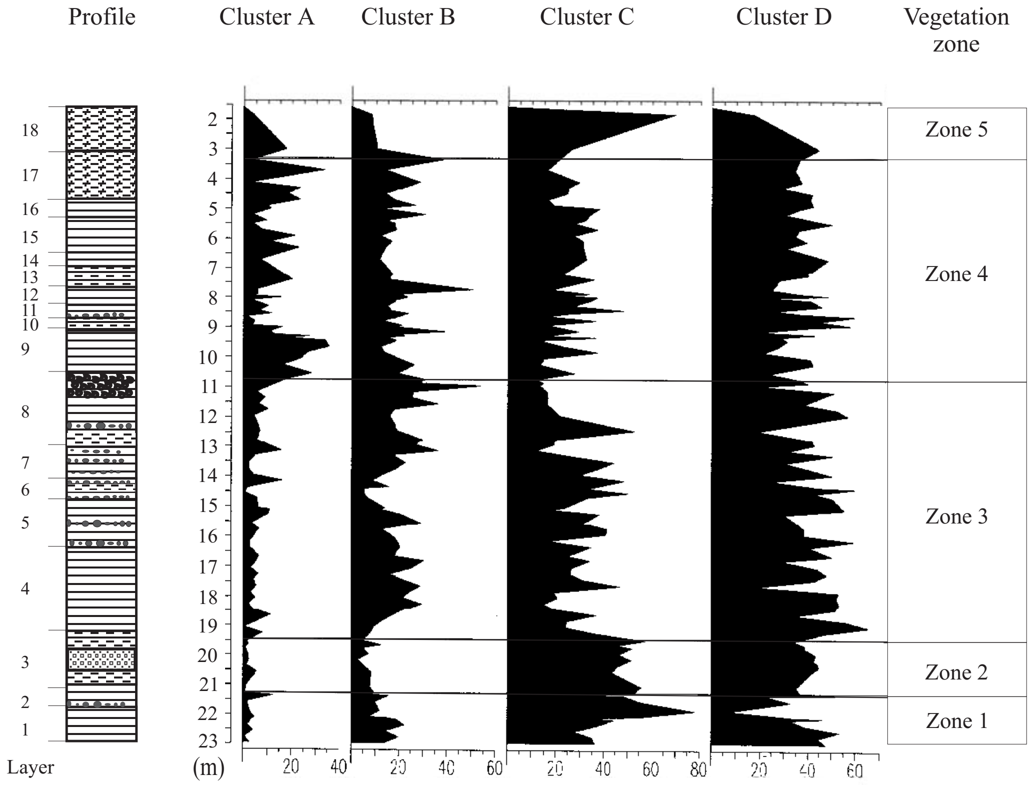

Fig. 11. Distribution of clusters through the Shanwang profile

Cluster D: *Carya*, *Quercus*, *Juglans*, and *Carpinus* are the most abundant taxa in this cluster, with accompanying taxa including *Acer*, Poaceae (Gramineae), *Ephedra* and Pteridaceae (refer to Fig. 9). This cluster is distributed evenly over the whole section, and comprises humid taxa (e.g. *Carya*, *Carpinus*, *Juglans*), upland taxa (e.g. *Quercus*, *Juglans*) and lowland taxa (e.g. *Carya*), the elements of the mixed mesophytic forest. From the ecological aspect, this cluster can be considered to represent a typical mixed mesophytic forest.

RECONSTRUCTION OF THE SHANWANG MIOCENE VEGETATION

In general composition of the Shanwang Miocene palynoflora basically belongs to the mixed mesophytic forest according to the floristic composition throughout the whole profile. However, as shown in Fig. 11, following the development of the four clusters in the Shanwang profile, the Shanwang Miocene vegetation can be divided into five vegetation zones (Tab. 6). These vegetation zones probably represent different developments of mixed mesophytic forest. Cluster D, which contains nearly 40% elements of the mixed mesophytic forest and is more or less evenly distributed with minor variations throughout the whole profile.

Vegetation zone 1: This vegetation occurs within the lowermost two layers (layers 1 and 2) from 22.95 to 21.25 m in the studied section, covering 13 samples. It is dominated by clusters C (*Ulmus–Zelkova* riparian forest), D (mixed mesophytic forest) and B (*Liquidambar–Pterocarya* riparian forest). It can be deduced that the mixed mesophytic forest in this zone included riparian areas around the lake.

Vegetation zone 2: This vegetation occurs in layer 3 from 21.25 to 19.45 m from which 9 samples were collected. It is dominated by clusters C (*Ulmus–Zelkova* riparian forest), D (mixed mesophytic forest), and shows a prominent reduction of the *Liquidambar–Pterocarya* riparian forest. From Fig. 9 it can be seen that *Tricolporopollenites wackersdorfensis* (extinct Fabaceae) interpreted as a dry element, is abundant during this stage. The evidence suggests that the mixed mesophytic forest included dry habitats in this zone.

Vegetation zone 3: This vegetation occurs from layer 4 to layer 8 between 19.45 and 10.75 m in the measured profile from which 47 samples were collected. This zone is similar to zone 1 and is dominated by clusters D (mixed

Table 6. Reconstruction of Shanwang Miocene vegetation

Vegetation zone	Characteristic palynological cluster	Mixed mesophytic forest
Vegetation zone 5 (9 samples)	Cluster C *Zelkova – Ulmus* riparian forest from more calcareous environments	Mixed mesophytic forest from more calcareous environments
Vegetation zone 4 (51 samples)	Cluster A upland *Fagus* forest from well-drained environments Cluster B *Liquidambar – Pterocarya* riparian forest Cluster C *Zelkova – Ulmus* riparian forest from more calcareous environments Cluster D mixed mesophytic forest	Diverse mixed mesophytic forest from various habitats (dry upland, riparian, alkaline soils, etc)
Vegetation zone 3 (47 samples)	Cluster B *Liquidambar – Pterocarya* riparian forest Cluster C *Zelkova – Ulmus* riparian forest from more calcareous environments Cluster D mixed mesophytic forest	Mixed mesophytic forest including riparian habitats
Vegetation zone 2 (9 samples)	Cluster C dominated by *Tricolporopollenites wackersdorfensis* probably from dry environments Cluster D mixed mesophytic forest	Mixed mesophytic forest including dry habitats
Vegetation zone 1 (11 samples)	Cluster B *Liquidambar – Pterocarya* riparian forest Cluster C *Zelkova – Ulmus* riparian forest from more calcareous environments Cluster D mixed mesophytic forest	Mixed mesophytic forest including riparian habitats

mesophytic forest), C (*Ulmus – Zelkova* riparian forest) and B (*Liquidambar–Pterocarya riparian forest*) but with a minor representation of *Tricolporopollenites wackersdorfensis*. It is most likely that this vegetation represents mixed mesophytic forest mostly from wet riparian habitat. Within this vegetation zone *Liquidambar–Pterocarya* riparian forest has a rapid reduction between 15.05 to 14.35 m that is accompanied by increases of *Tricolporopollenites wackersdorfensis* (see Fig. 9). This probably indicates that there are minor vegetation changes and the vegetation of zone 2 (mixed mesophytic forest from dry habitat) returns for a short period within this stage.

Vegetation zone 4: This vegetation occurs from layer 9 to layer 17 from 9.25 to 3.3 m in the measured profile from which a total 51 samples were collected. An abrupt increase of cluster A (upland *Fagus* forest from well-drained habitats) characterizes this vegetation which is markedly different from previous zones. The other three clusters B (*Liquidambar–Pterocarya* riparian forest), C (*Ulmus–Zelkova* riparian forest) and D (mixed mesophytic forest) are still present. This vegetation zone demonstrates that the mixed mesophytic forest during this stage is comparatively rich and comprises various taxa (e.g. *Fagus*, *Liquidambar*, *Pterocarya*, *Ulmus*, *Zelkova*, *Carya*, *Carpinus*, *Quercus*) from various different habitats (dry upland, wet riparian, alkaline soils etc.).

Vegetation zone 5: This vegetation is present in layer 18 and occurs between 3.3 to 1.8 m from which a total of 9 samples were collected. This vegetation is characterized by decreases in cluster A (upland *Fagus* forest from well-drained habitat), B (*Liquidambar–Pterocarya* riparian forest) and D (mixed mesophytic forest) with an increase in cluster C (*Ulmus–Zelkova* riparian forest). This vegetation zone probably represents the mixed mesophytic forest from more calcareous environments.

A POSSIBLE INTERPRETATION OF SHANWANG MIOCENE ENVIRONMENTAL CHANGE

Based on the Shanwang Miocene vegetation reconstruction, it is possible to deduce a pattern of environment change during the time of deposition (Fig. 12).

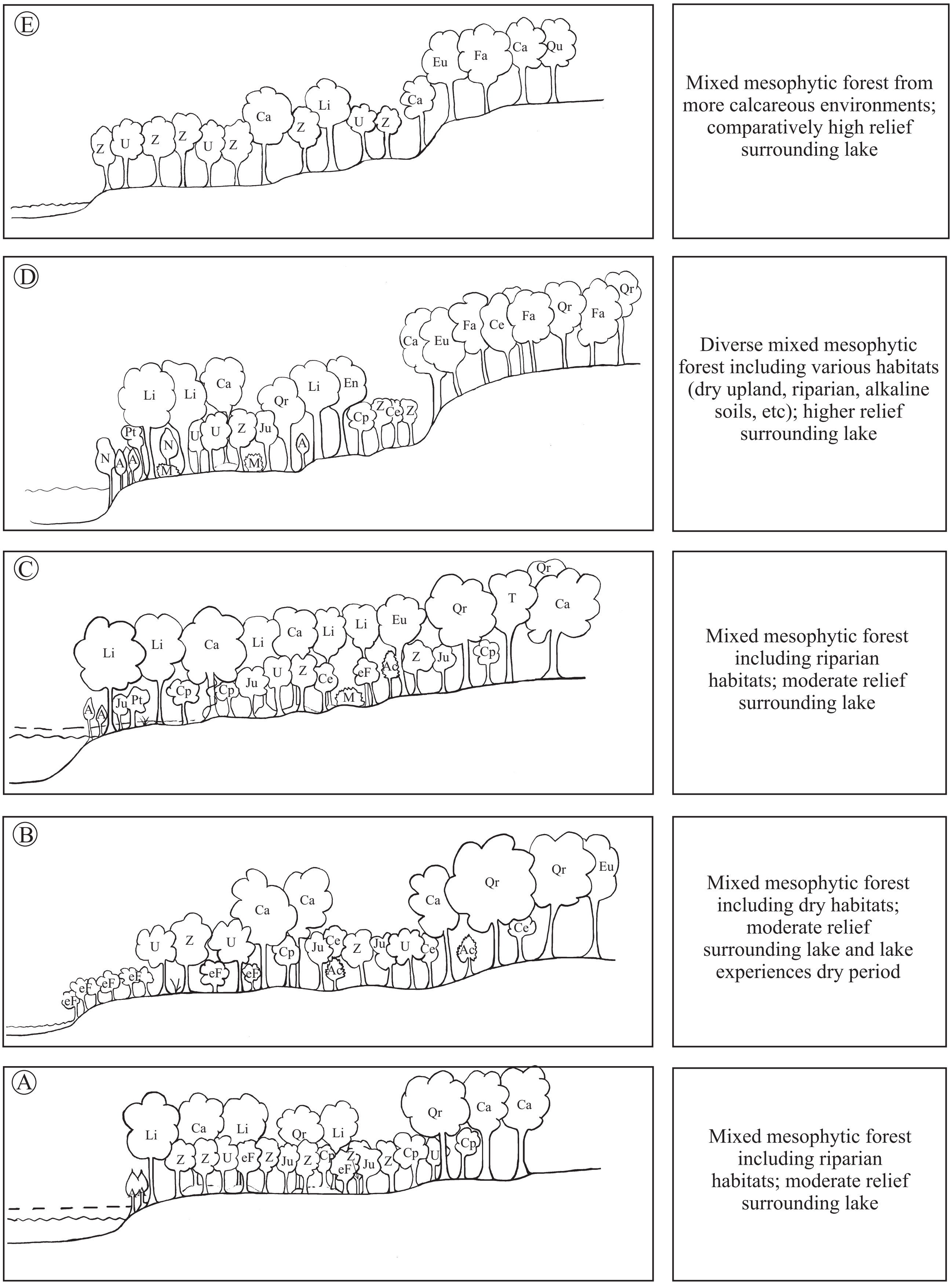

Fig. 12. Shanwang Miocene environments. Key to plants: **Li** – *Liquidambar*, **Ca** – *Carya*, **Z** – *Zelkova*, **U** – *Ulmus*, **A** – *Alnus*, **Pt** – *Pterocarya*, **eF** – extinct Fabaceae (*Tricolporopollenites wackersdorfensis*), **Qr** – *Quercus*, **Cp** – *Carpinus*, **Ju** – *Juglans*, **Ac** – *Acer*, **Ce** – *Celtis*, **Eu** – *Eucommia*, **M** – *Myrica*, **T** – *Tilia*, **N** – *Nyssa*, **En** – *Engelhardia*, **Fa** – *Fagus*.

During deposition of layers 1–2 the lake received sporomorphs from surrounding small hills suggested by the presence of a few upland forest species. The deciduous riparian forest elements were present extensively on the lake-shore belt (Fig. 12-A).

During deposition of layer 3 the vegetation around the lake was different from earlier. For example, *Liquidambar* the most sensitive element confined to humid soil environments disappeared, while extinct Fabaceae (*Tricolporopollenites wackersdorfensis*) which probably favoured dry soil environments rapidly expanded. This period did not last long and it had no obvious affect on the other less sensitive riparian plants (Fig. 12-B).

During deposition of layers 4–8 the periphery of the lake and surrounding areas with humid soil environments showed a return to diverse and extensive riparian deciduous forest. The influence of upland forests in the palyno-assemblages was lower. Large proportions of *Liquidambar* in contrast to the obviously declining amounts of *Tricolporopollenites wackersdorfensis* is diagnostic of this environmental change. A drier soil period probably returned for a short period during this stage in layer 6, suggested by a reduction in *Liquidambar* and an accompanying increase in *Tricolporopollenites wackersdorfensis* and Chenopodiaceae (Fig. 12-C).

The structures at the end of layer 8 resulted from turbidity flows that might have been caused by flood events or by tectonic movements. After sedimentation of bed 8 the area surrounding the lake, formerly a low hilly environment, presumably started to rise. These can be inferred from the increasing amounts of the upland forest element *Fagus* in subsequent vegetation. *Alnus* was an element of this vegetation that was a marsh element and it was present largely at the beginning of this vegetation succession, especially in layer 9. This suggests the presence of an increased amount of water, changing some of the local environments to more swampy conditions. Between layers 8–17 the areas surrounding the lake were occupied by a comparatively rich mixed mesophytic forest type flora, which comprised various taxa from various locations and habitats. During this time generally the lake slope was occupied by *Alnus* and marshy elements such as *Nyssa*, the lake shore belt was dominated by riparian deciduous forest including *Liquidamber*, *Pterocarya*, *Ulmus*, and *Carpinus* while the upland areas were covered by upland forests dominated by *Fagus* (Fig. 12-D).

During deposition of layer 18 the soils surrounding the lake probably became more calcareous, noted by the decrease in richness and abundance of the surrounding vegetation and the rise to dominance of the Ulmaceae (Fig. 12-E). The lake history was then concluded by the last sedimentary cycle that was a yellow-green mudstone from which palynological data were sparse and insufficient to deduce palaeoecological conclusions.

PALAEOCLIMATE

COEXISTENCE ANALYSIS FOR SHANWANG PALAEOCLIMATE

Using the coexistence approach (Mosbrugger & Utescher 1997) quantitative palaeoclimatic values have been obtained from the Shanwang palyno-assemblage. These include the mean annual temperature (MAT), temperature of the coldest month (TCM), temperature of the warmest month (TWM), temperature difference between coldest and warmest month (DT), mean annual precipitation (MAP), precipitation of the wettest month (PwetM), precipitation of the driest month (PDM), difference in precipitation between wettest and driest month (DP), precipitation of the warmest month (PwarmM) and relative humidity (RH). These 10 parameters are listed in Table 7, having been obtained from the total 112 pollen samples. The total 39 sporomorphs taxa used for coexistence analysis from all these samples are listed in Table 8.

As shown in Fig. 13, the climate intervals for each single sample are consistent for each parameter through the total 22.95 m profile.

The coexistence interval for the mean annual temperature (MAT) is from +15.6 – +17.2°C, bordered by *Engelhardia* and *Tsuga diversifolia* for a list of botanical affinities and respective sporomorph taxa. The coexistence interval of temperature of the coldest month (TCM) is +5.0 – +6.6°C, and the temperature of the warmest month (TWM) is +24.7 – +27.8°C; the coexistence intervals are bordered by *Engelhardia*, *Tsuga diversifolia* and *Engelhardia*, *Quercus* respectively. The coexistence interval of the temperature range

Table 7. Coexistence intervals of the palaeoclimate parameters on Shanwang profile, * successive number of taxa

Climate parameter	Climate value	Bordering taxa as well as corresponding palynomorph taxon numbers
MAT	15.6–17.2 (°C)	*Engelhardia* (27*, 28*) – *Tsuga diversifolia* (11)
TCM	5.0–6.6 (°C)	*Engelhardia* (27*, 28*) – *Tsuga diversifolia* (11)
TWM	24.7–27.8 (°C)	*Engelhardia* (27*, 28*) – *Quercus* (77*, 78*, 79*)
DT	20.5–25.0 (°C)	*Tsuga diversifolia* (11) – *Liquidambar* (39*, 40*, 41*)
RH	72–75 (%)	*Tsuga diversifolia* (11) – *Carya* (26)
MAP	1162–1281 (mm)	*Tsuga diversifolia* (11) – *Carpinus* (33)
PwetM	148–180 (mm)	*Tsuga diversifolia* (11) – *Juglans* (38)
PDM	16–59 (mm)	*Celtis occidentalis* (35) – *Zelkova* (47*, 48*)
DP	81–153 (mm)	*Tsuga diversifolia* (11) – *Tilia* (101)
PwarmM	108–111 (mm)	*Eucommia ulmoides* (64) – *Juglans* (38)

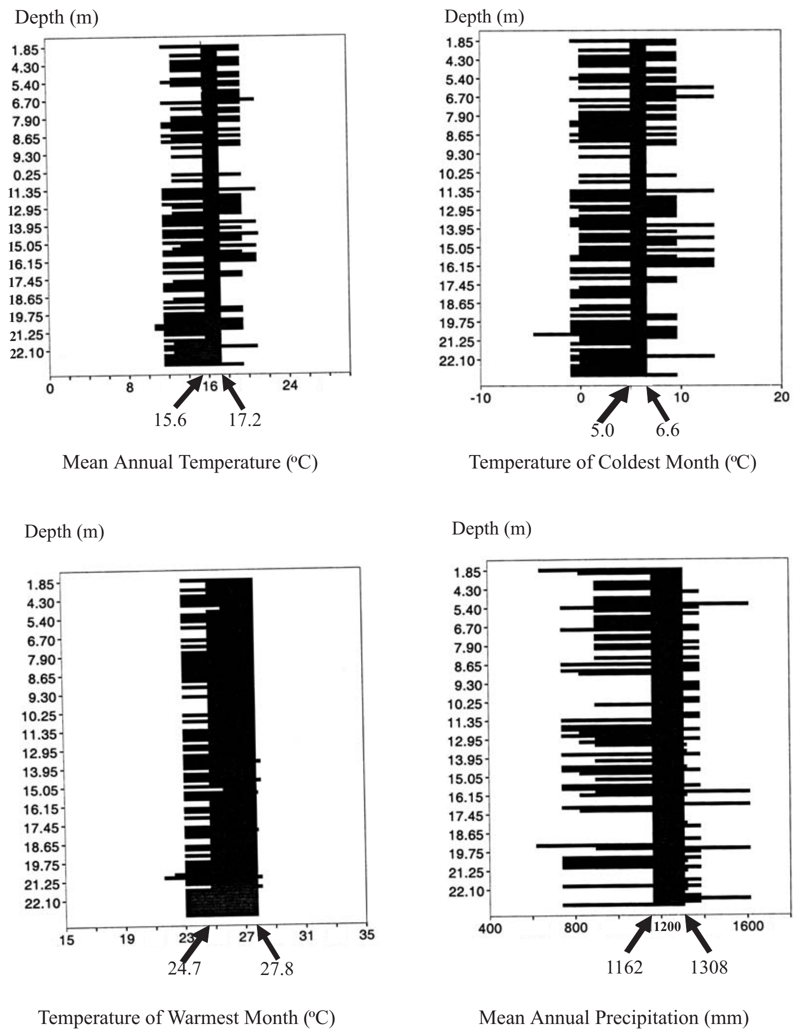

Fig. 13. Coexistence intervals for the Shanwang Miocene profile

between the warmest and coldest months is 20.5–25°C that is bordered by *Tsuga diversfolia* and *Liquidambar*.

As for precipitation, the mean annual precipitation determined is between 1162 mm and 1281 mm, and these coexistence intervals are bordered by *Tsuga diversifolia* and *Carpinus*. In this case, the genus *Ephedra* has been excluded as it forms a climatic outlier and indicates low MAP values which are significantly

Table 8. The palynomorph taxa used in coexistence analysis

Taxon number	Fossil palynomorph taxon	Nearest living relative
1	*Aceripollenites striatus*	*Acer* sp.
2	*Alnipollenites verus*	*Alnus* sp.
3	*Trivestibulopollenites betuloides*	*Betula* sp.
4	*Carpinipites carpinoides*	*Carpinus* sp.
5	*Caryapollenites simplex*	*Carya* sp.
6	*Celtipollenites intrastructurus*	*Celtis occidentalis*
7	*Chenopodipollis* sp.	Chenopodiaceae
8	*Momipites punctatus*	*Engelhardia* sp.
9	*Engelhardioidites microcoryphaeus*	*Engelhardia* sp.
10	*Ephedripites* sp.	*Ephedra* sp.
11	*Eucommiaceoipollenites eucommides*	*Eucommia ulmoides*
12	*Faguspollenites verus*	*Fagus* sp.
13	*Faguspollenites crassus*	*Fagus* sp.
14	*Faguspollenites gemmatus*	*Fagus* sp.
15	*Ilexpollenites propinquus*	*Ilex* sp.
16	*Juglandipollis juglandoides*	*Juglans* sp.
17	*Periporopollenites formosanaeformis*	*Liquidambar* sp.
18	*Periporopollenites orientaliformis*	*Liquidambar* sp.
19	*Periporopollenites styracifluaeformis*	*Liquidambar styraciflua*
20	*Triatriopollenties bituitus*	*Myrica* sp.
21	*Nyssapollenites kruschi accessorius*	*Nyssa* sp.
22	*Nyssapollenites kruschi analepticus*	*Nyssa* sp.
23	*Oleoidearumpollenites microreticulatus*	Oleaceae
24	*Piceapollis* div.sp.	*Picea* sp.
25	*Persicarioipollis franconicus*	*Polygonum* sp.
26	*Persicarioipollis welzowense*	*Polygonum* sp.
27	*Pterocaryapollenites stellatus*	*Pterocarya* sp.
28	*Quercopollenites petraea* type	*Quercus* sp.
29	*Quercopollenites robur* type	*Quercus* sp.
30	*Quercopollenites granulatus*	*Quercus* sp.
31	*Inaperturopollenites concedipites*	Taxodiaceae
32	*Intratriporopollenites instructus*	*Tilia* sp.
33	*Zonalapollenites igniculus*	*Tsuga* sp.
34	*Zonalapollenites maximus*	*Tsuga* sp.
35	*Zonalapollenites minispinus*	*Tsuga* sp.
36	*Zonalapollenites spinosus*	*Tsuga diversifolia*
37	*Ulmipollenites undulosus*	*Ulmus* sp.
38	*Zelkovaepollenites potoniei*	*Zelkova* sp.
39	*Zelkovaepollenites thiergartii*	*Zelkova* sp.

drier than all the other values determined (refer to the Material and Methods section). The coexistence interval of precipitation for the driest month is 16–59 mm and is combined from two single intervals, following the protocols utilized by Mosbrugger & Utescher (1997). In this case the range is from the combination of the interval between 16–18 mm that is bordered by *Celtis* and *Ulmus* and the interval of 26–59 mm that is bordered by *Fagus* and *Zelkova*. These ranges have both been retained as they both seem reasonable and a single interval accommodates both. The coexistence interval of the precipitation of the wettest month is between 148–180 mm and is bordered by *Tsuga diversifolia* and *Juglans*. In this case *Engelhardia* is excluded as it indicates a value of 204 mm as the lowest precipitation boundary that is much higher than the value indicated by all other taxa. The precipitation of the warmest month is between 108–111 mm and is determined by the ranges for *Eucommia ulmoides* and *Juglans*. The difference between the precipitation of the wettest and driest months is between 81–153 mm, bordered by *Tsuga diversifolia* and *Tilia*, which is also combined from two single intervals, an interval of 81–87 mm that is bordered by *Tsuga diversifolia* and *Carya*, and an interval of 104–153 mm that is bordered by *Eucommia ulmoides* and *Tilia* and excludes *Engelhardia*. The relative humidity is from 72–75%.

From the above climate parameters, it can be deduced that Miocene Shanwang palaeoclimate was warm temperate, humid, with moderately cool winters and hot summers.

COMPARISON WITH MODERN COMPARABLE CLIMATE TYPES

Köppen (1923, 1931) classified the earth's climate into five zones, and named them by A–E respectively. According to this climate classification and previously gathered palaeoclimatic information, the Shanwang Miocene climate was comparable to the "Cfa-climate" type that is characterized by a warm-temperate climate with high humidity, cool winters and hot summers. This climate zone has temperature for the coldest month between –3 and +18°C, temperature of the warmest month of > +22°C, and high precipitation throughout the year.

Differing from Köppen's climate classification, Walter (1962) divided the global climate into 10 climate types corresponding to 10 different vegetation zones that he numbered from I to X. According to this method of classification the Shanwang Miocene palaeoclimate was comparable to climate type "V" that is characterized by a humid warm temperate climate. This climate zone corresponds to the warm-temperate evergreen vegetation zones that are distributed in the areas of the coastal margins of all the continents especially those of eastern Asia.

Troll & Paffen (1980) gave another system of climate classification that included five climate zones numbered from I to V. Like Walter's (1962) earlier classification, these climate zones are consistent with the corresponding vegetation zones. However, this system of classification take into account other climate parameters including climatic variability between days, years, marine and continental climates. In this system the Shanwang Miocene climate was comparable to the type "IV, 7" climate which is characterized by high humidity throughout the year, hot summers with maximum precipitation, and present in subtropical humid forest areas.

Based on the above described climate classification systems, the several recent meteorological stations from eastern Asia which have most similar climate to that of the Miocene Shanwang have been recognised (Fig. 14),

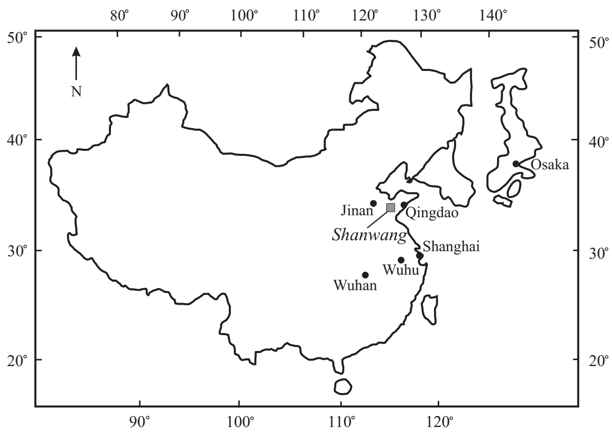

Fig. 14. Location map of present day meteorological stations

namely those with a "Cfa-climate" according to Köppen (1931), a "V" climate according to Walter (1962), and a "IV, 7" climate type according to Troll & Paffen (1980), as shown in Table 9.

Among the above described meteorological stations, the climate spectra from Wuhan (Sträßer 1998) and Wuhu (Walter 1962) are

Table 9. Recent climate data corresponding to Shanwang Miocene climate (after Walter 1962, Walter et al. 1975, Müller 1996, Sträßer 1998)

Meteorological station	Altitude(m)	MAT (°C)	TCM (°C)	TWM (°C)	MAP (mm)	Climate type		
						Köppen 1923,1931	Walter et al. 1975	Troll & Paffen 1980
Wuhan (Hankow) (China)	23	+16.8	+3.8	+28.9	1194	Cfa	V	IV, 7
Wuhu (China)	36–55	+16.3	+4.0	+28	1183	Cfa	V	IV, 7
Shanghai (China)	5	+15.3	+3.4	+27.2	1135	Cfa	V	IV, 7
Osaka (Japan)	7	+15.5	+4.5	+27.8	1360	Cfa	V	IV, 7

closest to the Miocene Shanwang climate as reconstructed in this work. It is not only on their similarity of mean annual temperature (MAT), temperature of the coldest month (TCM), temperature of the warmest month (TWM) and mean annual precipitation (MAP), but also on their similar rainfall distributions. The climate from Wuhan (Editorial Committee on vegetation of China 1980, Sträßer 1998) and Wuhu (Walter 1962, Walter et al. 1975), which are located along the middle and lower Chang Jiang River (Yangzi River) respectively, are considered to be representatives of the Miocene Shanwang climate (Fig. 15). This conclusion supports the earlier findings of Chaney & Hu (1940) who determined the same region to be comparable to the Shangwang plant fossil assemblage, although the coexistence approach using pollen gives greater climate resolution than achieved by Chaney & Hu (1940).

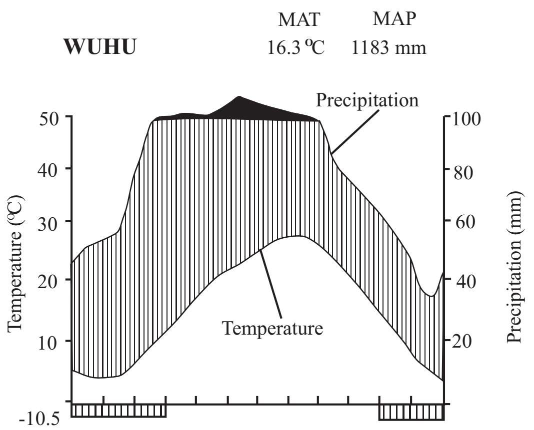

Fig. 15. Climate diagram of Wuhu (after Walter et al. 1975)

From the results of the coexistence approach presented here it can be deduced that Miocene Shanwang palaeoclimate was a warm temperate, humid climate, with cool winters and hot summers. This is like the climate types from the modern middle and lower areas of the Chang Jiang (Yangzi) River and comparable to the "Cfa-climate" type of Köppen (1923, 1931), the "V" climate type of Walter (1962), and the "IV, 7" climate type of Troll & Paffen (1980).

COMPARISON WITH THE MODERN SHANWANG CLIMATE

The Shanwang area is about 200 km east from Jinan and about 200 km northwest from Qingdao (Fig. 14). Concerning its present day climate type (Tab. 10, Fig. 16), this part of

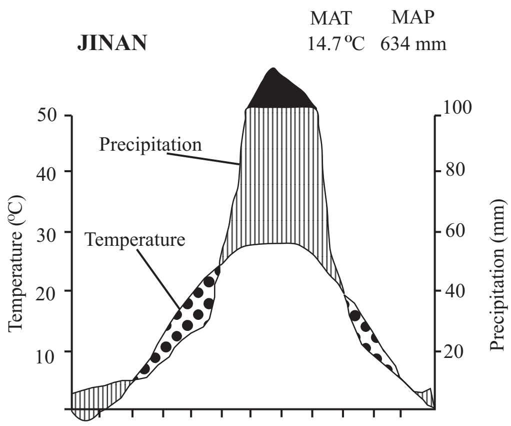

Fig. 16. Climate diagram of present day Shanwang (after Walter et al. 1975)

Shandong is considered to be within Köppen's "Cwa-climate" type zone. This is characterized by a warm, humid climate with temperatures of the coldest month between –3 to +18°C, with the hottest month over +22°C and with abundant summer precipitation that is at least 10 times greater than the rare winter precipitation (Müller 1996, Sträßer 1998). According to Walter's system, this part of Shandong province is within the "VI" climate and vegetation zone, characterized by a temperate climate with a short cold season or nearly frost free winters, with corresponding temperate

Table 10. The modern Shanwang area climate data (after Walter 1962, Walter et al. 1975, Müller 1996, Sträßer 1998). (In order to provide direct comparison, the Miocene Shanwang climate data are also shown in this table).

Meteorological station	Altitude (m)	MAT (°C)	TCM (°C)	TWM (°C)	MAP (mm)	Climate type		
						Köppen 1923, 1931	Walter et al. 1975	Troll & Paffen 1980
Miocene Shanwang		+15.6 – +17.2	+5.0 – +6.6	+24.7 –+27.8	1162 – 1281	Cfa	V	IV, 7
Present Shanwang (Jinan)	55	+14.8	–2	+27	631	Cwa	VI	III, 7
Present Shanwang (Qingdao)	77	+12.1	–2.5	+26	648	Cwa	VI-V	III, 7

deciduous vegetation zone distributed in eastern North America, middle and west Europe and eastern Asia (Walter 1962, Walter et al. 1975). Finally, this region corresponds to Troll & Paffen's zone "III 7" that is humid throughout the year and has hot, wet summers (Müller 1996).

The main difference between the Miocene Shanwang climate and the modern climate from Jinan and Qingdao meteorological stations is the mean annual precipitation (MAP), rainfall distribution, and also the temperature of the coldest month (TCM). The Miocene precipitation of Shanwang was almost 2 times greater than that of Jinan and Qingdao, with humid, uniformly distributed rainfall throughout the year. This is in contrast to the seasonal (spring and autumn) drought in Jinan, and uneven distribution of the rainfall in Jinan and Qingdao where rainfall is largely confined to the summer months (Walter et al. 1975). In contrast to the present day cold and dry winters with temperatures of the coldest month (TCM) below 0°C (typically –2.5 to –2.0°C), the Miocene Shanwang had a warm, humid winter with the TCM clearly over 0°C (+5.0 to +6.6°C). However, as far as the mean annual temperature and temperature of the warmest month are concerned, there is no great difference between the Miocene and present day climates.

COMPARISON WITH PREVIOUS STUDIES ON SHANWANG PALAEOCLIMATE

The results presented here from the coexistence approach are broadly comparable to that identified by Chaney & Hu (1940) who determined the Shanwang climate to be "warm temperate to subtropical, with average temperatures well above freezing, and with adequate precipitation uniformly distributed throughout the year". However, it is clear that the categories identified by Chaney and Hu (op.cit.) form a general climatic framework rather than providing precise values.

Song (1959) considered the Shanwang palynoflora to be representative of a subtropical temperate climate which is consistent with the findings from this study, although the absence of precise results from Song's study prevents further comparison. The report presented by Writing Group of Cenozoic Plants of China (1978) concluded that the Shanwang climate was warm and humid, and transitional between warm temperate and subtropical climates. This again is consistent with the present study. The findings of Li (1981) essentially mirror those of Chaney & Hu (1940) and Song (1959).

Palaeoclimatic evidence from diatoms (Skvortzov 1937, Li 1982) suggests northern temperate climates and subtropical southern climates. This result is also consistent to that presented on the Shanwang fish fauna by Young & Tchang (1936). However, in both instances these results indicate water conditions and no other parameters comparable to those determined in this study, although these conclusions do not contradict with those presented in the present investigation.

Results from oxygen isotopes (Shi 1990) suggest Shanwang water temperatures higher than +21°C in summer. This value is generally consistent with the TWM of +24.7 – +27.8°C determined in this investigation, and is agreeable with both MAT and DT values. The same isotope evidence also suggests winter water temperatures to be lower than +13.4°C which is also consistent with the TCM determined in this study of +5.0 – +6.6°C. While this isotope method is accurate for determining water temperature it only indicates indirectly an approximate value for the air temperatures, and as such is not considered a reliable method for terrestrial palaeoclimatic inferences.

The palaeoclimatic results based on nearest living relatives presented by Liu & Leopold (1992) largely follow those presented by Chaney & Hu (1940) although introduce more accurate values through a semi-quantitative approach (Liu & Leopold op.cit.). The climatic parameters determined by Liu & Leopold included mean annual temperature (MAT), temperature of the warmest month (TWM), temperature of the coldest month (TCM), and mean annual precipitation (MAP). In general Liu & Leopold's results are supported by the present investigation, with precipitation predictions largely consistent (e.g. near or slightly above 1000 mm), while the predictions on the temperature related parameters are slightly cooler than the present prediction in each case (e.g. MAT +13.5 – +16.5°C, TCM +2 – +3°C, TWM +23 – +26°C).

Recently, Sun et al. (2002) quantitatively reconstructed the Shanwang palaeoclimate using the CLAMP method on leaf megafossils. They determined 9 climate parameters including mean annual temperature (MAT), warmest month mean temperature (WMMT), mean growing season precipitation (MGSP) and relative humidity (RH). In general, the precipitation and humidity predictions were very similar to those determined in the coexistence analysis results presented here (e.g. MGSP 83–165 cm, RH 73–79%), but temperature predictions were much cooler (e.g. MAT +9.5 – +11.2°C, WMMT +20.2 – +22.5°C). Sun et al. (2002) explained that one possible reason causing the cooler climate prediction is because the leaf flora is slightly biased due to the lacustrine setting with a higher proportion of serrate-margined leaves giving a cooler climate signal.

In general the palaeoclimatic results from the Shanwang assemblage are complimentary, especially those based on the nearest living relative methods (e.g. Chaney & Hu 1940, Liu & Leopold 1992, and the present coexistence analysis study). Other results are either less precise but still showing the same overall climatic situation (Skvortzov 1937, Song 1959, Writing Group of Cenozoic Plants of China 1978, Li 1981, 1982) or use less reliable methods for assessing palaeoclimates (e.g. Shi 1990). This indicates that despite the use of different techniques on different plant based data sets, the underlying climatic signals have been detected from the fossil assemblage.

SYNTHESIS: MIOCENE SHANWANG VEGETATION AND CLIMATE, ENVIRONMENTAL CHANGE

From the coexistence analysis undertaken in this study it has been determined that the palaeoclimate prevailing throughout the formation of the Shanwang fossil flora was warm, humid climate with mean annual temperature ranged from +15.6 – +17.2°C and mean annual precipitation ranged from 1162–1281 mm. The reconstructed vegetation which is based on cluster analysis, and ecological tolerances of nearest living relatives indicates that the vegetation succession and environments changed during deposition of the studied section.

From the bottom to the top the relief surrounding the lake changed from an area of more or less even relief to one with larger scale topography with upland in close proximity. Correspondingly, the vegetation succession around the lake changed from mixed mesophytic forest dominated by riparian deciduous elements with few members of upland forest, to a diverse mixed mesophytic forest representing various habitats, and finally to a mixed mesophytic forest from more calcareous habitats which was dominated by members of the Ulmaceae.

The Shanwang Basin was fault bounded by the Tan-Lu Fault system to the east which had a controlling role on the regional structure. Intensified activity of fault movements during Miocene may be the possible mechanism for the changes in Shanwang habitats. In particular, fault activity may have locally changed relief producing locally uplifted fault blocks, and these may have had knock on effects on soils surrounding the lake and also on the water systems supplying it. It is suggested here that these changes were most likely to have resulted in the vegetation succession and environment change expressed in the Shanwang palynoflora.

According to the coexistence analysis, an equable climate characterized this sedimentary period. However, slight climate fluctuation, which is beyond the coexistence analysis climate resolution, may have caused variations in plant proportions but not enough to alter the whole vegetation type.

Tertiary alkaline basalts were widely exposed in the Shanwang region. The vegetation change into the mixed mesophytic forest with more calcareous elements (vegetation zone 5) may reflect increased erosion or exposure of these basalts.

CONCLUSION

The Shanwang Basin in Shandong Province, eastern China is a world famous locality that contains an exceptionally well-preserved fossil biota including diverse assemblages of fossil plants and animals. In this project the palynology of the Shanwang Basin has been studied in detail, based on a total of 133 pollen samples, stratigraphically collected from a 22.95 m diatomaceous profile. From these samples a detailed taxonomic investigation of Shanwang palynology has been conducted to reconstruct the Shanwang Miocene palaeoecology and palaeoclimate.

T a x o n o m y. In the present investigation the composition and distribution of sporomorphs throughout the Shanwang geological profile has been studied in detail. A total of 108 taxa have been described and illustrated. Along with each taxon, information on its botanical affinities, general stratigraphic occurrences and frequency in the Shanwang profile, has been presented.

P a l a e o e c o l o g y. Using cluster analysis, seventy taxa have been used to reconstruct Shanwang Miocene palaeovegetation and palaeoenvironments. These indicate that the Shanwang Miocene vegetation was a mixed mesophytic forest. During sedimentation, this mixed mesophytic forest experienced five distinct stages:

1) Mixed mesophytic forest including riparian habitats

2) Mixed mesophytic forest including dry habitats

3) Mixed mesophytic forest including riparian habitats

4) Diverse mixed mesophytic forest from various habitats which included dry upland, riparian and alkaline soils

5) Mixed mesophytic forest from more calcareous environments

P a l a e o c l i m a t e. Using the coexistence approach, 112 pollen samples and 39 sporomorph taxa have been used to quantitatively calculate the Miocene Shanwang climate. The result of the coexistence analysis demonstrates that there is no significant climate change during the deposition of this sequence. Ten of the most informative climatic variables for the Miocene Shanwang climate give the following results:

– mean annual temperature: +15.6 – +17.2°C
– temperature of the coldest month: +5.0 – +6.6°C
– temperature of the warmest month: +24.7 – +27.8°C
– difference of temperatures of the coldest and warmest month: 20.5 – 25.0°C
– relative humidity: 72–75%
– mean annual precipitation: 1162–1281 mm
– precipitation of the wettest month: 148–180 mm
– difference of precipitation of driest and wettest months: 16–59 mm
– precipitation of the driest month: 81–153 mm
– precipitation of the warmest month: 108–111 mm.

ACKNOWLEDGEMENTS

This Ph.D. project was co-supervised by Professor Dr. Li Cheng-Sen (Department of Palaeobotany, Institute of Botany, Chinese Academy of Sciences, Beijing) and Professor Dr. Volker Mosbrugger (Institute of Geology and Palaeontology, University of Tübingen, Germany), to whom I express my extreme gratitude and thanks for their inspiration and ideas, for facilitating my study visit to Germany, and for providing financial support for this project. In China I wish to thank Du Nai-Qiu for help with sporomorph recognition and advice in processing palynological samples. I would also like to thank Prof. Wang Shi-Jun, Song Shu-Yin, Prof. Wang Yu-Fei, Prof. Zhu Wei-Qing, Dr. Liu Yan-Ju, Dr. Liu Zhao-Hua, Dr. Feng Guang-Ping, Dr. Sun Qi-Gao, Dr. Chen Li-Qun, and Dr. Shang Hua for help and support throughout this project. Prof. Wang Xian-Zeng (Beijing University) is thanked for help with sporomorph recognition, Prof. Li Feng-Lin (Beijing Geology University) for assistance in resolving stratigraphical problems, and Prof. Wang Pu-Jun (Changchun Geology University) for help with sedimentary analysis and facies interpretations. In Germany I wish to express my gratitude for assistance from Dr. Angela Bruch (Tübingen) for her help in every aspect of this work. Dr. Rahman Ashraf (Tübingen) for help with palynological techniques and classification, Tobias Schneck for help with computer hardware and software, Eva for assistance with laboratory techniques, and Luci Schlemmer for her assistance throughout my stay in Germany. I also thank Gabi, Sunia and Jana Mosbrugger, and Dr. Sigl Erkart for their companionship throughout my stay in Germany, and for making my stay in Tübingen so pleasant. I wish to thank my parents for their understanding and support for my work and for their support with my two years stay in Germany. I wish to thank Dr Jason Hilton (University of Birmingham) who helped with the final stages of this project, and who still firmly believes that pollen and spores should have shorter names. Prof. Margaret E. Collinson (Royal Holloway University of London) and Dr. Maria Ziembińska-Tworzydło (Department of Geology, Warsaw University) are thanked for their critical reviews and comments on this manuscript that have greatly improved this work. This work has benefited greatly from reviews, comments and the careful editing of Prof. Leon Stuchlik (W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków), and also the help and support of Dr Jan Wójcicki of the same institute, both of which are highly appreciated.

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PLATES

Plate 1

(×1000)

(1) ***Polypodiaceoisporites gracillimus*** Nagy 1963 ssp. ***granoverrucatus*** Krutzsch 1967

1a,b. Slide B31-2 (155.7/ 7.1)

(2) ***Laevigatosporites gracilis*** Wilson & Webster 1946

2a,b. Slide B11-1 (143.2/ 13.0)

3a,b. Slide A32-1 (148.5/ 9.9)

(4) ***Verrucatosporites favus*** (Potonié 1931) Thomson & Pflug 1953 ssp. ***favus*** Krutzsch 1967

4a,b. Slide A6-2 (152.6/ 7.0)

6a,b. Slide A46-1 (155.2/ 16.6)

7. Slide A7-1 (134.4/ 6.4)

(3) ***Laevigatosporites haardti*** (Potonié & Venitz 1934) Thomson & Pflug 1953 ssp. ***haardti*** Krutzsch 1967

5. Slide A22-2 (154.4/ 12.8)

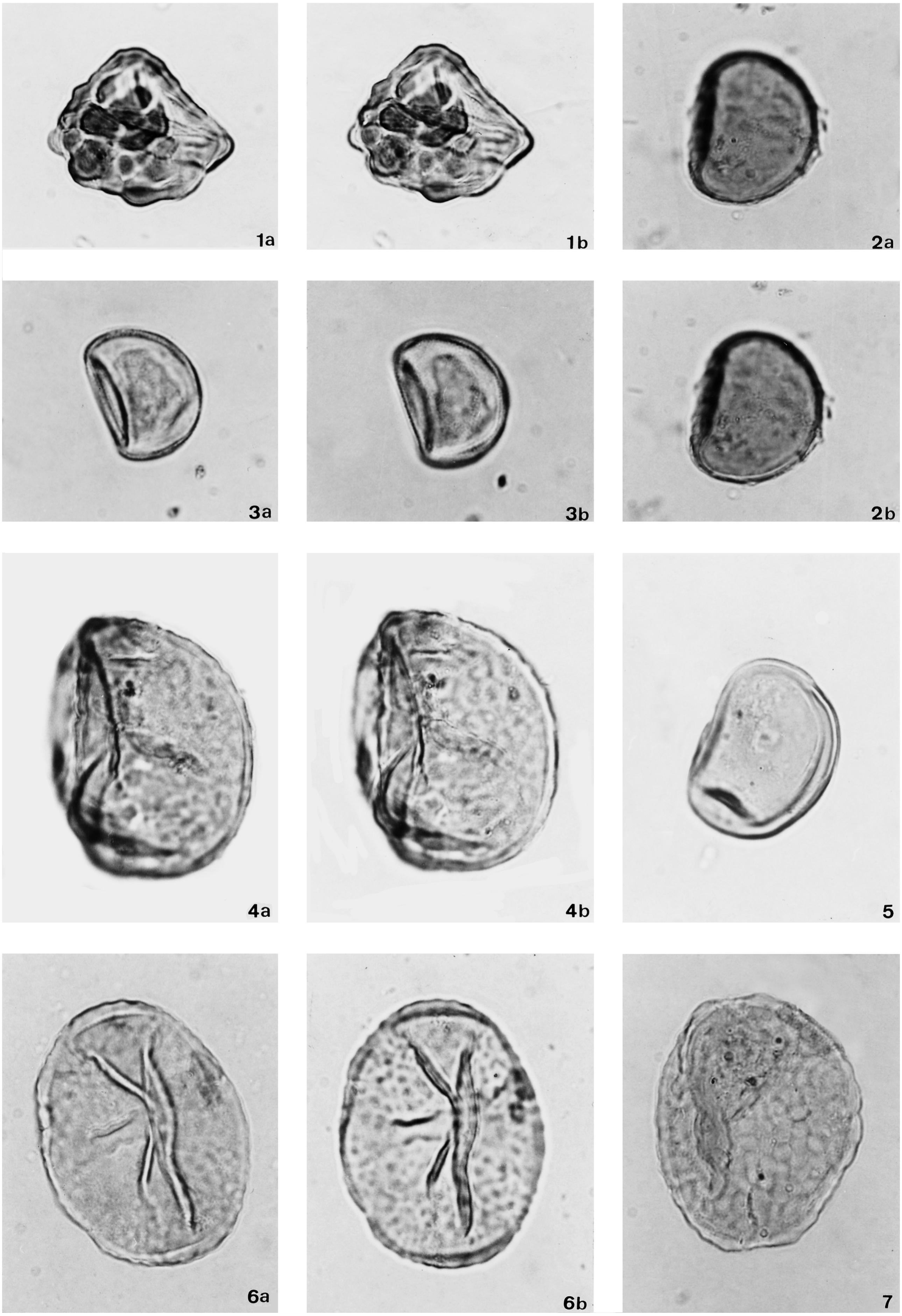
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Plate 2

(×1000) except * (×400)

(8) ***Zonalapollenites igniculus*** (Potonié 1931) Thomson & Pflug 1953

1a,b. Slide A33-2 (139.6/16.9)

*(14) ***Pityosporites*** div. sp.

2a,b. Slide A41-2 (133.6/7.4)
3a,b. Slide A8-2 (155.0/6.5)

(11) ***Zonalapollenites spinosus*** (Doktorowicz-Hrebnicka 1964) Ziembińska-Tworzydło 1974

4a,b. Slilde A48-2 (140.9/8.8)
5. Slide A33-2 (137.3/4.7)

(9) ***Zonalapollenites maximus*** (Raatz 1937) Krutzsch 1971 ex Ziembińska-Tworzydło 1974

6. Slide A49-2 (152.1/5.3)

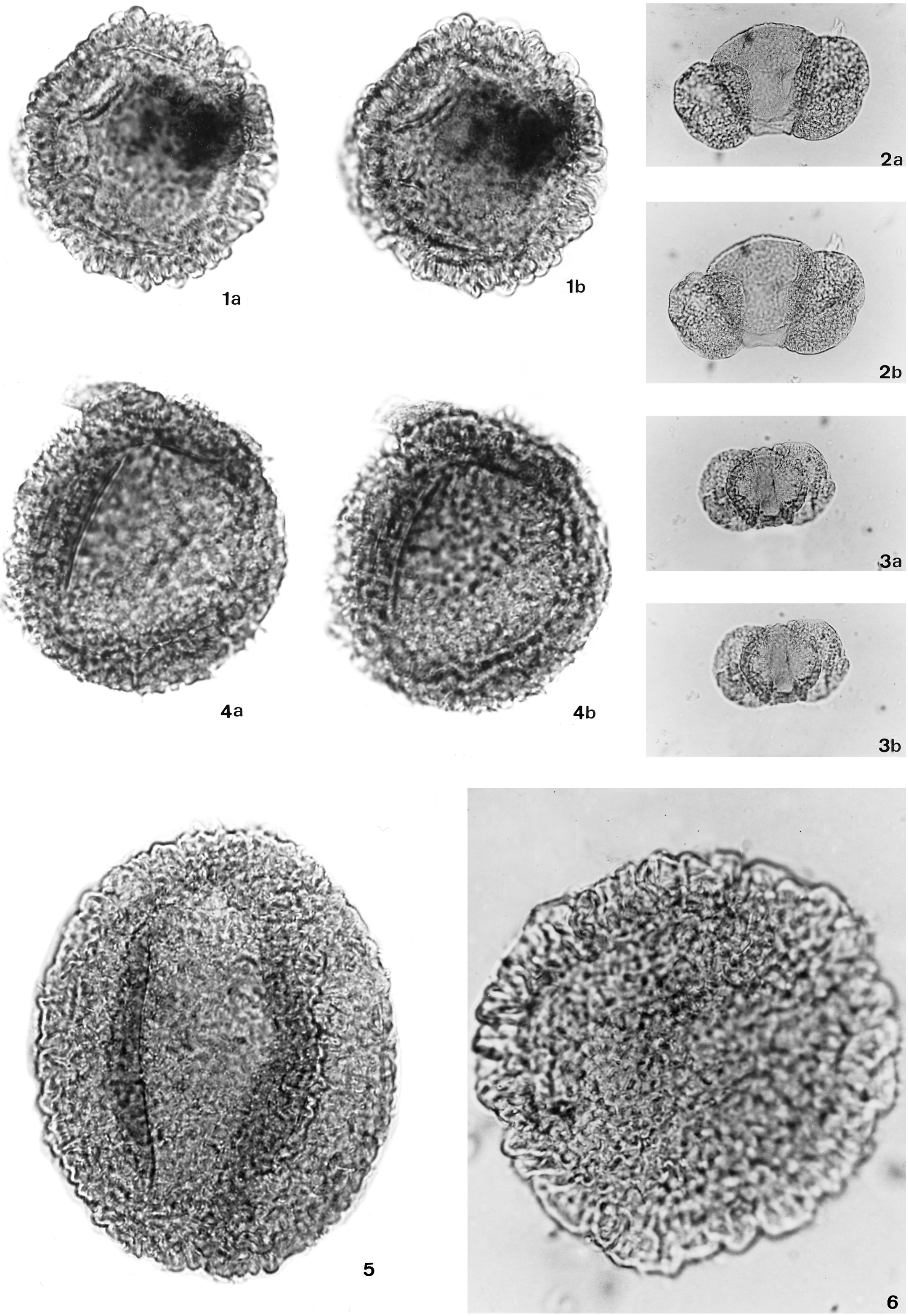
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Plate 3

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*(13) ***Piceapollis*** sp.

1a,b. Slide A37-2 (154.5/10.5)

(5) ***Inaperturopollenites concedipites*** (Wodehouse 1933) Krutzsch 1971

2. Slide A42-2 (149.5/23.3)
3. Slide A30-1 (137.7/2.5)

*(12) ***Abiespollenites*** div. sp.

4. Slide B12-2 (140.8/10.0)

(7) ***Sciadopityspollenites serratus*** (Potonié & Venitz 1934) Raatz 1937 ex Potonié 1958

5. Slide A17-2 (139.4/5.4)
8. Slide A33-2 (146.6/19.7)

(6) ***Sequoiapollenites largus*** (Kremp 1949) Manum 1962

6. Slide B23-1 (144.1/17.6)

(22) ***Arecipites convexus*** (Thiergart 1937) Krutzsch 1970

9. Slide A41-2 (135.5/6.0)

(20) ***Ephedripites (Distachyapites) fushunensis*** Sung & Tsao 1980

7a,b. Slide B12-2 (130.4/16.0)

(17) ***Cycadopites*** cf. ***minimus*** (Cookson 1947) Krutzsch 1970

10. Slide A33-2 (150.0/9.7)

11a,b. Slide A33-2 (138.9/3.3)

(19) ***Ephedripites (Distachyapites) fusiformis*** (Shakmundes 1965) Krutzsch 1970

12a,b. Slide B8-1 (140.4/10.0)

(18) ***Ephedripites (Distachyapites) cheganicus*** (Shakmundes 1965) Ke & Shi 1978

13. Slide A10-1 (148.3/7.3)

(21)***Ephedripites (Ephedripites) wolkenbergensis*** Krutzsch 1961

14. Slide B63-2 (154.3/22.1)

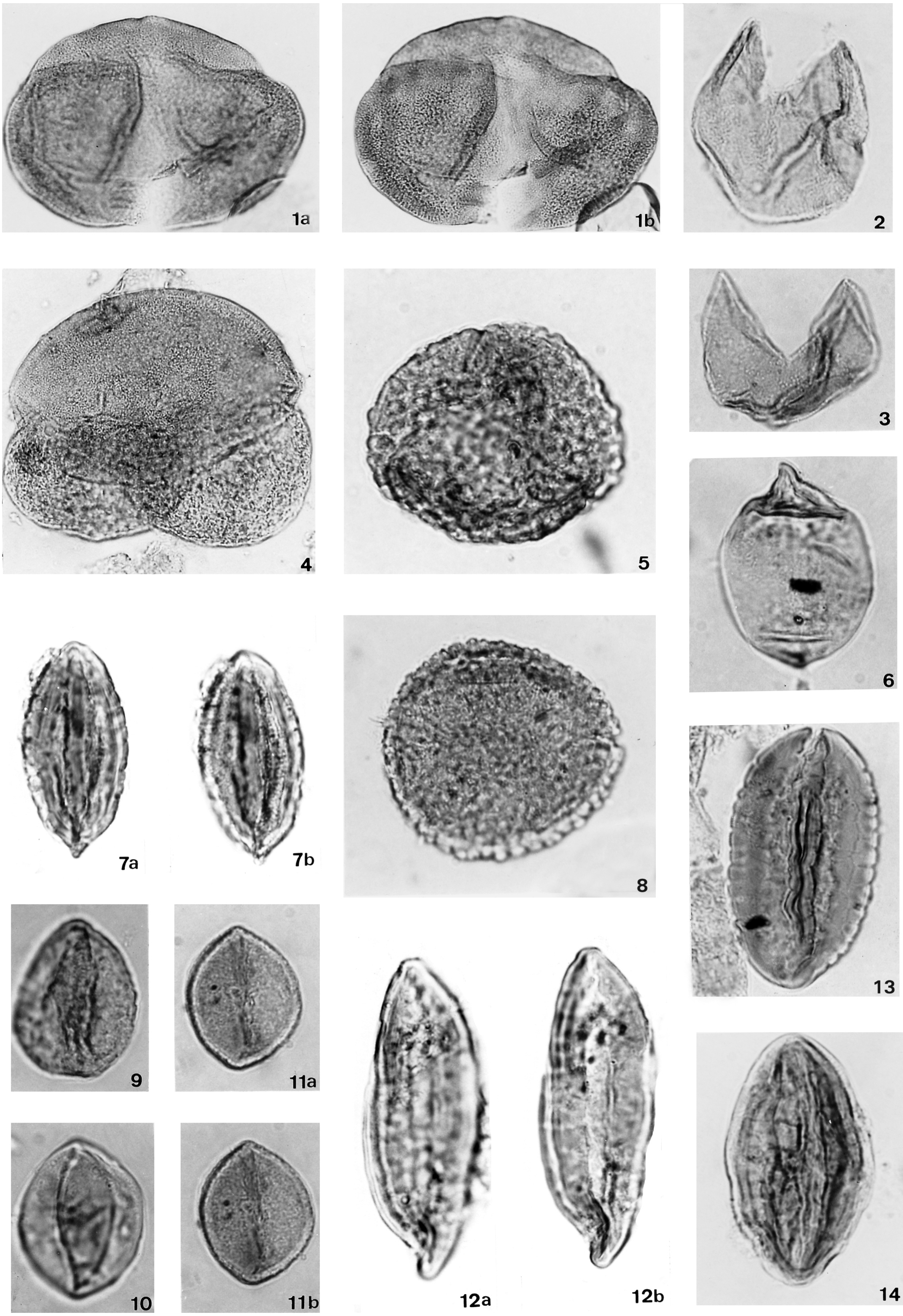
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Plate 4

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(16) ***Cycadopites microfollicularis*** Krutzsch 1970

1a,b. Slide B23-1 (134.6/13.1)

(59) ***Tricolpopollenites* sp. 1**

2. Slide B17-2 (133.4/11.6)

(60) ***Tricolpopollenites* sp. 2**

3. Slide A7-2 (147.7/8.0)

(79) ***Quercopollenites robur*** type Nagy 1969

4a,b. Slide B32-2 (135.0/14.5)
8a,b. Slide B32-2 (142.9/10.8)

(54) ***Tricolpopollenites asper*** Pflug & Thomson in Thomson & Pflug 1953

5. Slide B32-2 (153.0/9.4)
6. Slide A30-1 (141.4/13.9)
7. Slide A43-2 (144.8/9.9)

(78) ***Quercopollenites petraea*** type Nagy 1969

9a, b. Slide A34-1 (153.0/4.4)
10a, b. Slide A28-2 (148.2/12.8)

(55) ***Tricolpopollenites henrici*** (Potonié 1931) Thomson & Pflug 1953

11. Slide A30-1 (152.3/5.6)

(77) ***Quercopollenites granulatus*** Nagy 1969

12. Slide B32-1 (134.5/12.9)

(90) ***Tricolporopollenites pseudocingulum*** (Potonié 1931) Thomson & Pflug 1953

13a-c. Slide A7-2 (138.0/12.1)

(70) ***Ilexpollenites propinquus*** (Potonié 1934) Potonié 1960

14a–c. Slide B32-2 (149.8/19.3)

(99) ***Vitispollenites tener*** Thiele-Pfeiffer 1980

15. Slide B32-1 (142.3/7.5)

(81) ***Rhuspollenites ornatus*** Thiele-Pfeiffer 1980

16a,b. Slide A36-2 (141.7/14.6)

(61) ***Tricolpopollenites* sp. 3**

17a–c. Slide A7-2 (147.1/14.0)
18a–c. Slide B32-2 (147.4/10.8)

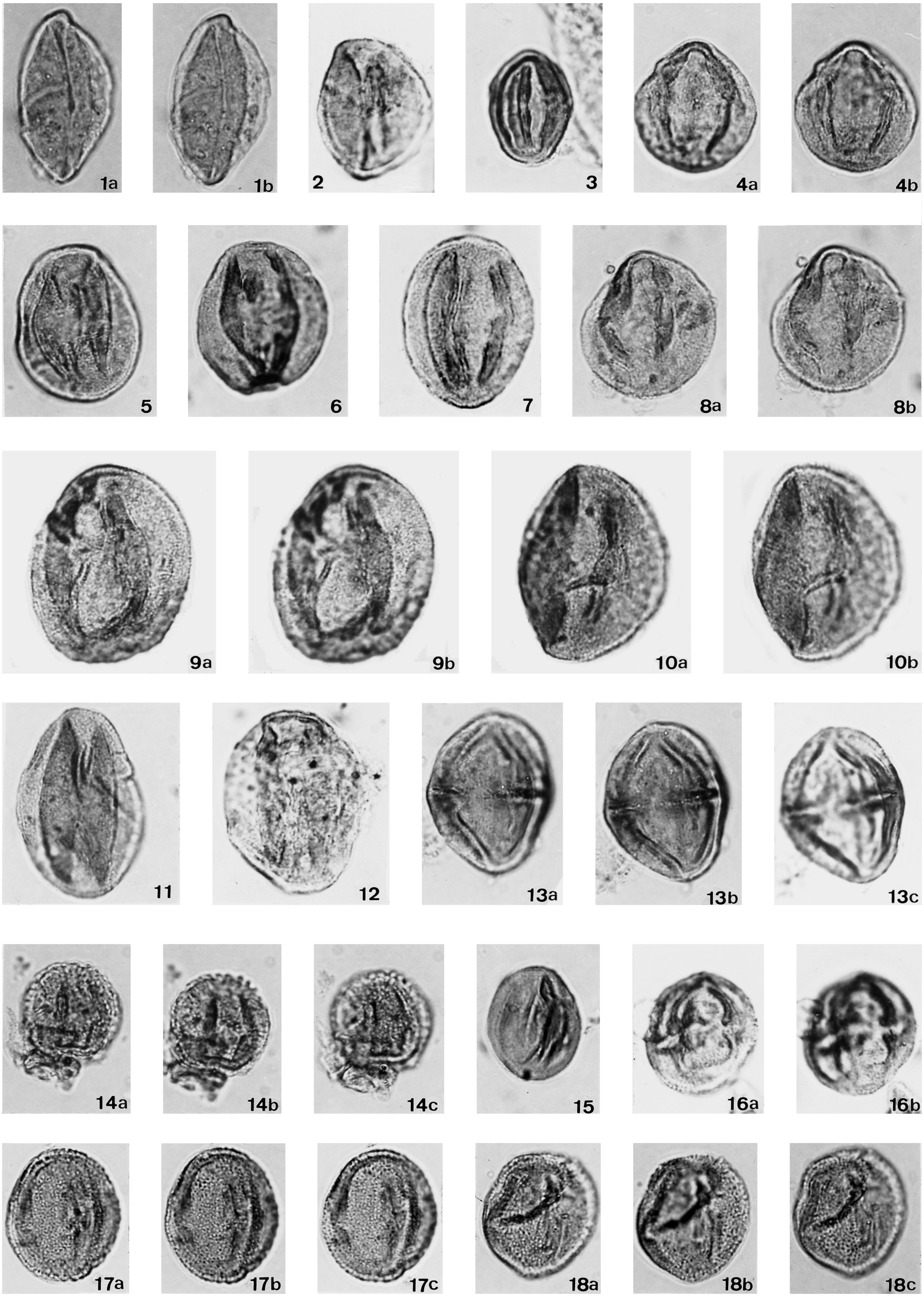
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Plate 5

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(57) ***Tricolpopollenites minimireticulatus*** Trevisan 1967

1. Slide B38-1 (143.5/14.6)

(52) ***Ranunculacidites pachydermus*** Zheng 1989

2. Slide A34-1 (150.7/9.3)

(50) ***Aceripollenites striatus*** (Pflug 1959) Thiele-Pfeiffer 1980

3a,b. Slide A7-1 (143.7/10.7)
6a,b. Slide A7-1 (146.4/22.0)

(58) ***Tricolpopollenites*** cf. ***sinuosimuratus*** Trevisan 1967

4a,b. Slide B32-2 (138.9/12.9)

(35) ***Celtipollenites intrastructurus*** (Krutzsch & Vanhoorne 1977) Thiele-Pfeiffer 1980

5. Slide A30-1 (133.7/15.3)
7a,b. Slide A34-1 (154.8/9.4)
9. Slide A34-1 (144.6/17.5)
10a,b. Slide A30-1 (135.2/6.7)

(34) ***Celtipollenites komloensis*** Nagy 1969

8a,b. Slide A25-2 (137.9/7.6)

(88) ***Tricolporopollenites megaexactus*** (Potonié 1931) Thomson & Pflug 1953
ssp. ***exactus*** (Potonié 1931) Thomson & Pflug 1953

11. Slide B29-2 (134.8/11.7)

(83) ***Tricolporopollenites*** cf. ***cingulum*** (Potonié 1931) Thomson & Pflug 1953

12. Slide A7-2 (140.0/15.6)
13. Slide A7-2 (149.2/13.1)

(74) ***Oleoidearumpollenites microreticulatus*** (Pflug & Thomson 1953) Ziembińska-Tworzydło 1994

14a–c. Slide A32-2 (144.9/3.5)

(51) ***Operculumpollis operculatus*** Sun, Kong & Li 1980

15a–c. Slide A30-1 (137.5/4.9)

(85) ***Tricolporopollenites edmundi*** (Potonié 1931) Thomson & Pflug 1953

16. Slide A34-1 (152.2/13.8)

(87) ***Tricolporopollenites marcodurensis*** Pflug & Thomson in Thomson & Pflug 1953
Type 2 after Bruch 1998

17a–c. Slide B32-2 (137.5/12.8)

(82) ***Tricolporopollenites cingulum*** (Potonié 1931) Thomson & Pflug 1953
ssp. ***oviformis*** (Potonié 1931) Thomson & Pflug 1953

18a,b. Slide A43-2 (145.3/3.2)

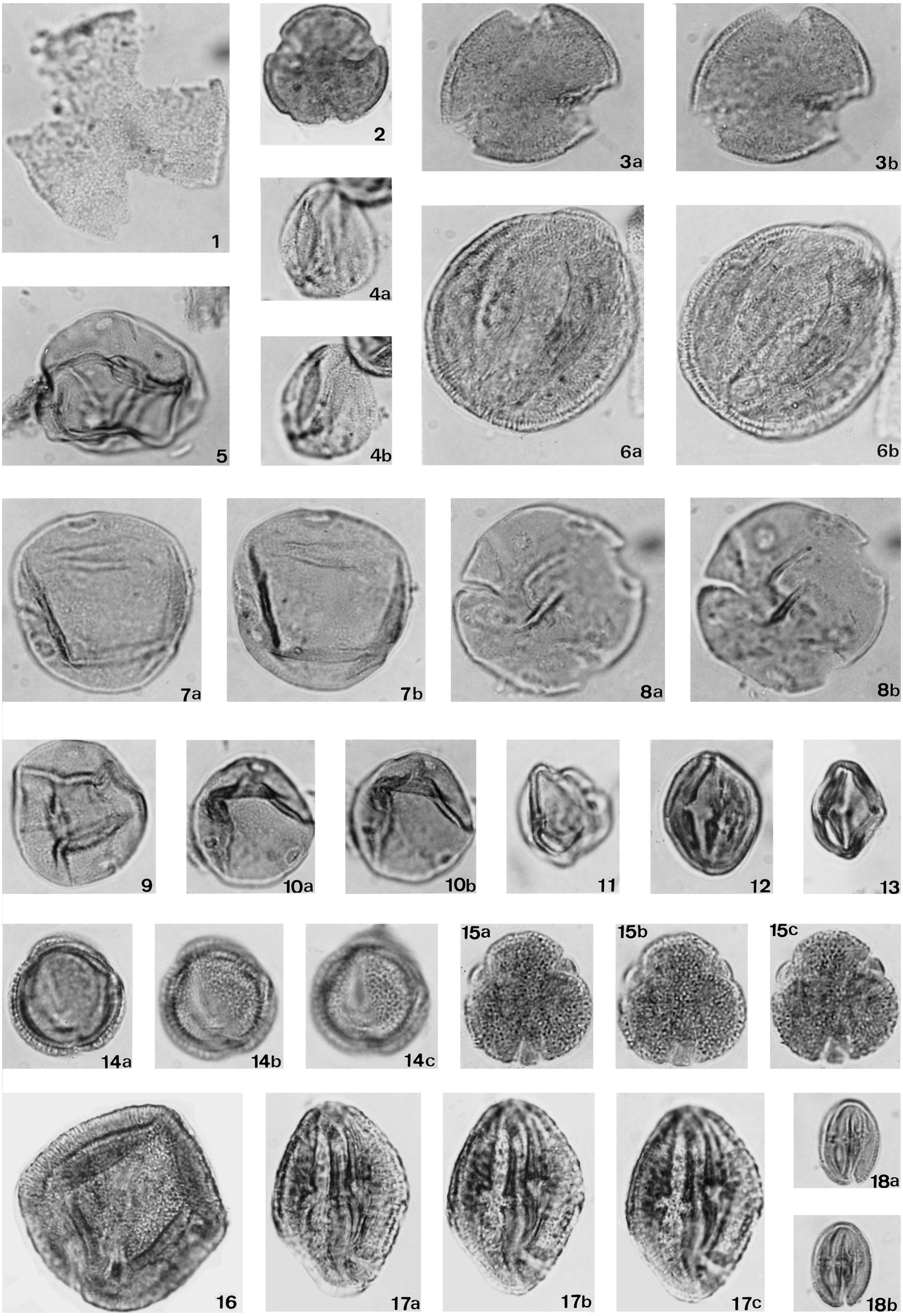
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Plate 6

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(86) ***Tricolporopollenites marcodurensis*** Pflug & Thomson in Thomson & Pflug 1953
Type 1 after Bruch 1998

1a–c. Slide B35-1 (139.3/7.9)

(92)***Tricolporopollenites* sp. 1**

2. Slide A41-2 (140.8/4.6)

(107) ***Tubulifloridites granulosus*** Nagy 1969

3a–c. Slide B29-2 (143.1/8.3)

(64) ***Eucommiaceoipollenites eucommides*** M. R. Sun 1989

4. Slide A7-2 (142.7/6.0)

(75) ***Oleoidearumpollenites reticulatus*** Nagy 1969

5a,b. Slide A7-1 (135.5/21.0)

(91) ***Tricolporopollenites wackersdorfensis*** Thiele-Pfeiffer 1980

6a,b. Slide A34-1 (133.7/9.8)
7a,b. Slide A7-2 (153.8/5.8)

(93) ***Tricolporopollenites* sp. 2**

8a,b. Slide B29-2 (135.4/10.6)

(94) ***Tricolporopollenites* sp. 3**

9a,b. Slide B29-2 (135.4/10.6)

(95) ***Tricolporopollenites* sp. 4**

10a,b. Slide A3 (151.1/15.4)

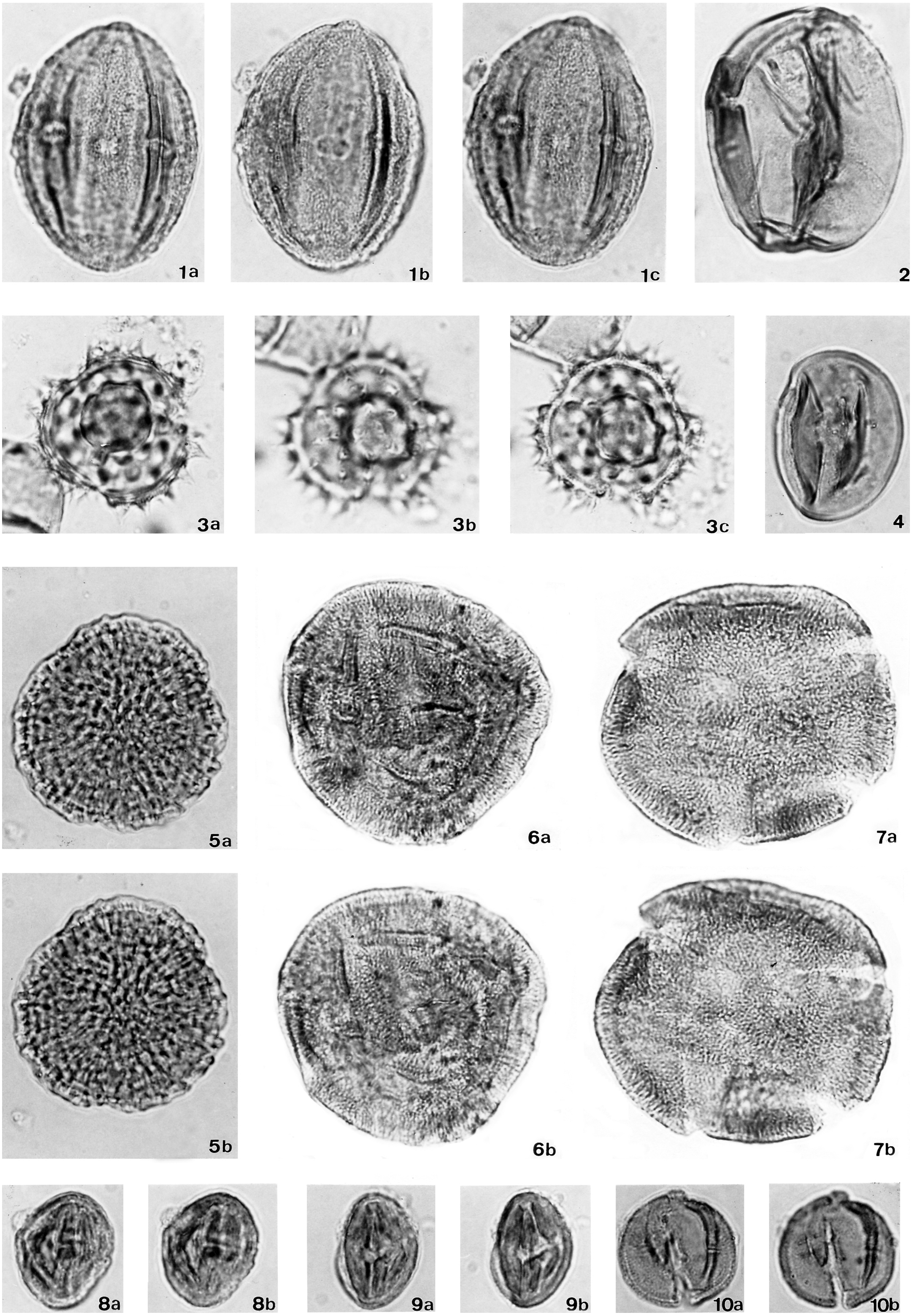
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Plate 7

(×1000)

(90) ***Tricolporopollenites pseudocingulum*** (Potonié 1931) Thomson & Pflug 1953

1a,b. Slide A27 (138.0/5.6)
8a,b. Slide A25-2 (138.5/7.6)
9a,b. Slide A7-2 (155.8/5.9)

(89) ***Tricolporopollenites megaporatus*** Bruch 1998

2a,b. Slide A12-1 (133.0/13.0)

(73) ***Nyssapollenites kruschi*** (Potonié 1931) Potonié, Thomson & Thiergart 1950
ssp**. *rodderensis*** (Thiergart 1937) comb. nov.

3. Slide B13-1 (142.5/9.9)

(96) ***Tricolporopollenites* sp. 5**

4a,b. Slide A7-2 (153.1/6.4)
5. Slide A8-2 (131.1/15.6)

(84) ***Tricolporopollenites dolium*** (Potonié 1931) Thomson & Pflug 1953

6. Slide A37-2 (138.5/12.6)
12a,b. Slide B58-2 (141.9/7.3)

(56) ***Tricolpopollenites microhenrici*** (Potonié 1931) Thomson & Pflug 1953

7a,b. Slide A12-1 (148.9/12.8)

(80) ***Rhoipites striatus*** Zheng 1985

10a,b. Slide A47-1 (151.0/5.6)
13. Slide A45-2 (137.4/13.7)

(69) ***Horniella fusiformis*** (Song & Qian 1989) Song 1999

11a–c. Slide A35-1 (142.0/22.5)

(53) ***Ranunculacidites vulgaris*** Song & G.X. Li 1989

14a,b. Slide B26-1 (149.4/20.6)

(52) ***Ranunculacidites pachydermus*** Zheng 1989

15. Slide A8-2 (144.4/6.4)

(97) ***Tricolporopollenites* sp. 6**

16. Slide B34-2 (139.4/6.7)
17. Slide A30-1 (142.0/12.1)

(98) ***Tricolporopollenites* sp. 7**

18a,b. Slide A14-1 (140.0/9.9)

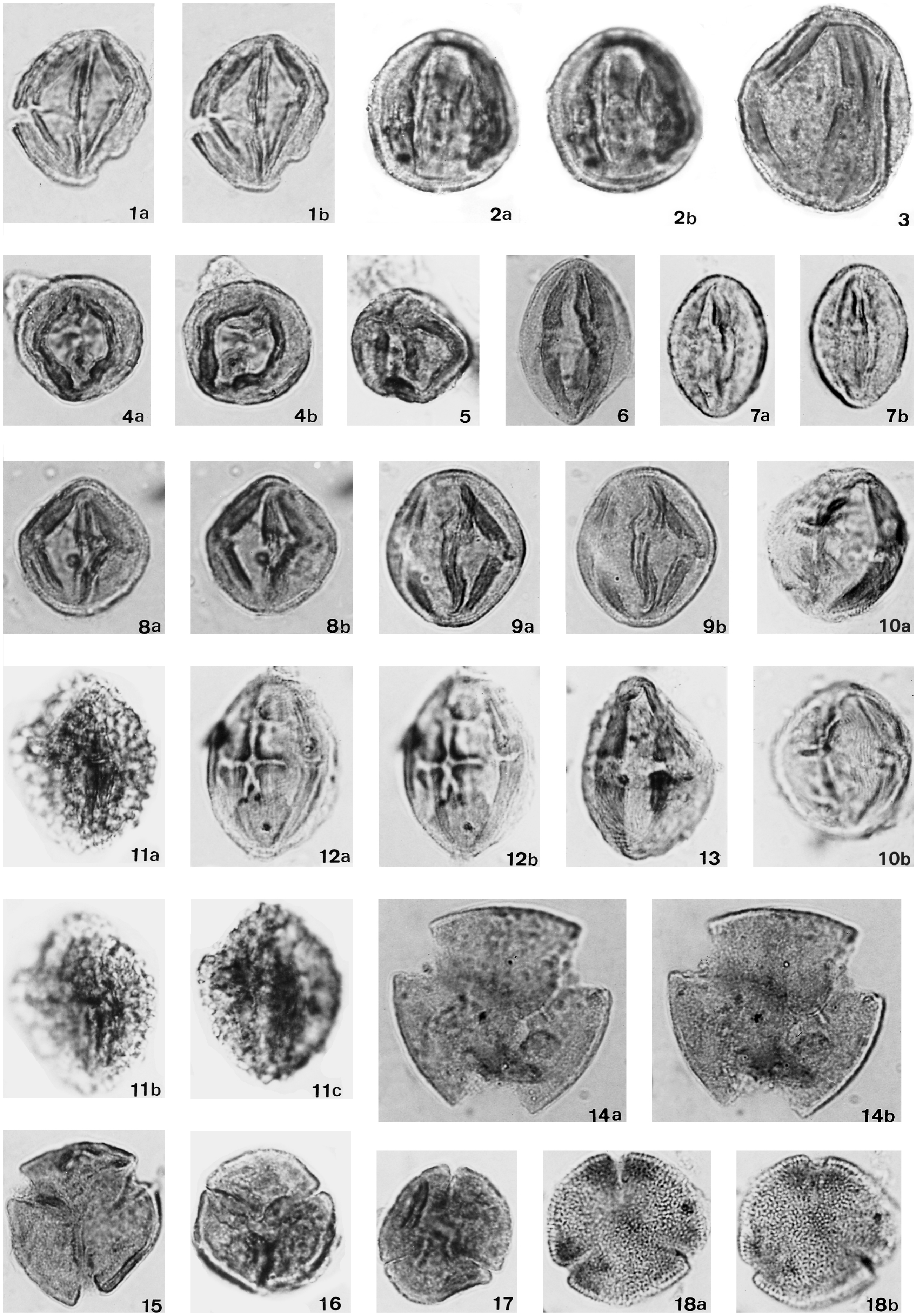
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Plate 8

(×1000)

(65) ***Faguspollenites crassus*** Nagy 1969

1a,b. Slide A30-1 (133.8/5.2)
2. Slide B32-1(142.5/14.2)

(68) ***Faguspollenites verus*** Raatz 1937 ex Potonié 1960

3a,b. Slide A8-2 (144.2/2.3)
4a,b. Slide A8-2 (154.5/3.6)
5a,b. Slide A7-2 (153.9/15.8)
7a,b. Slide A7-2 (138.6/7.3)

(66) ***Faguspollenites gemmatus*** Nagy 1969

6a–c. Slide A7-2 (139.3/6.1)
8. Slide A7-2 (155.1/7.4)
9. Slide A7-2 (144.1, 10.9)

(71) ***Nyssapollenites kruschi*** (Potonié 1931) Potonié, Thomson & Thiergart 1950
ssp. ***accessorius*** (Potonié 1934) Potonié, Thomson & Thiergart 1950

10a,b. Slide B23-1 (146.7/5.5)

(72) ***Nyssapollenites kruschi*** (Potonié 1931) Potonié, Thomson & Thiergart 1950
ssp. ***analepticus*** (Potonié 1934) Nagy 1969

11a,b. Slide A10-1 (137.0/14.6)

(63) ***Artemisiaepollenites sellularis*** Nagy 1969

12a,b. Slide A45-2 (138.3/14.0)
13. Slide A32-1 (147.5/16.0)

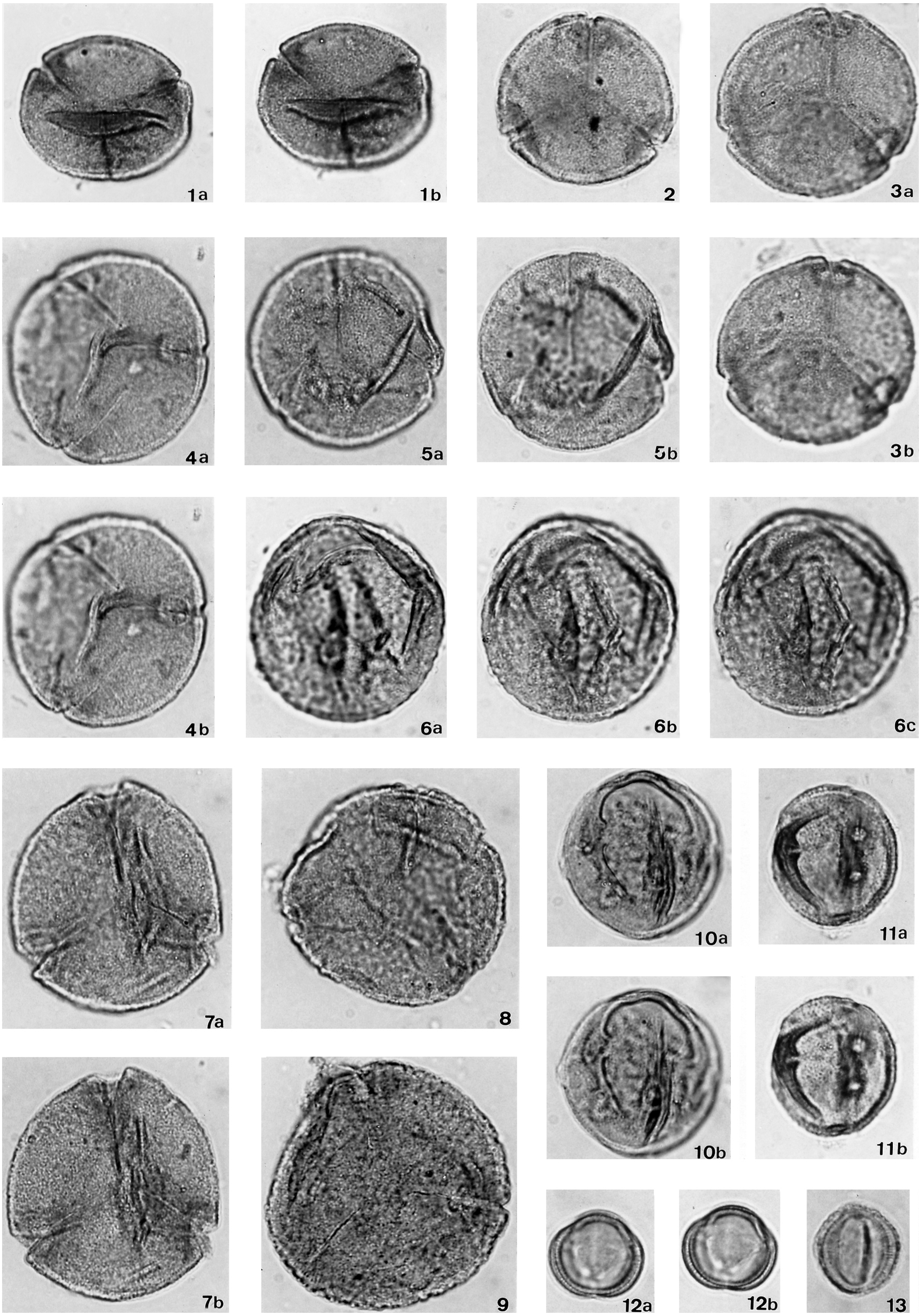
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Plate 9

(×1000)

(62) ***Alangiopollis barghoornianum*** (Traverse 1955) Krutzsch 1962

1a,b. Slide B46-1 (142.2/11.2)

(63) ***Artemisiaepollenites sellularis*** Nagy 1969

2a–c. Slide A2-2 (141.0/5.0)

(72) ***Nyssapollenites kruschi*** (Potonié 1931) Potonié, Thomson & Thiergart 1950 ssp. ***analepticus*** (Potonié 1934) Nagy 1969

3a,b. Slide A28-2 (150.8, 11.8)

(66) ***Faguspollenites gemmatus*** Nagy 1969

4. Slide A8-2 (132.8/3.5)

(68) ***Faguspollenites verus*** Raatz 1937 ex Potonié 1960

5. Slide A8-2 (135.6/4.2)

(71) ***Nyssapollenites kruschi*** (Potonié 1931) Potonié, Thomson & Thiergart 1950 ssp. ***accessorius*** (Potonié 1934) Potonié, Thomson & Thiergart 1950

6. Slide A20-2 (146.6/7.8)

(65) ***Faguspollenites crassus*** Nagy 1969

7. Slide B26-1 (155.7/15.7)

(76) ***Pokrovskaja originalis*** Boitzova 1979

8a,b. Slide A8-2 (155.1/4.7)

9a–c. Slide A7-2 (138.2/6.7)

(25) ***Graminidites pseudogramineus*** Krutzsch 1970

10a,b. Slide A46-1 (134.1/13.4)

(24) ***Graminidites micropunctatus*** Krutzsch 1970

11a,b. Slide A32-1 (140.9/17.8)

(28) ***Momipites punctatus*** (Potonié 1931) Nagy 1969

13a,b. Slide A33-2 (137.0/11.7)

14. Slide A26-1 (152.9/18.4)

(27) ***Engelhardioidites microcoryphaeus*** (Potonié 1931) Potonié 1960

12. Slide A49-2 (141.7/7.4)

15. Slide B8-1 (153.6/15.5)

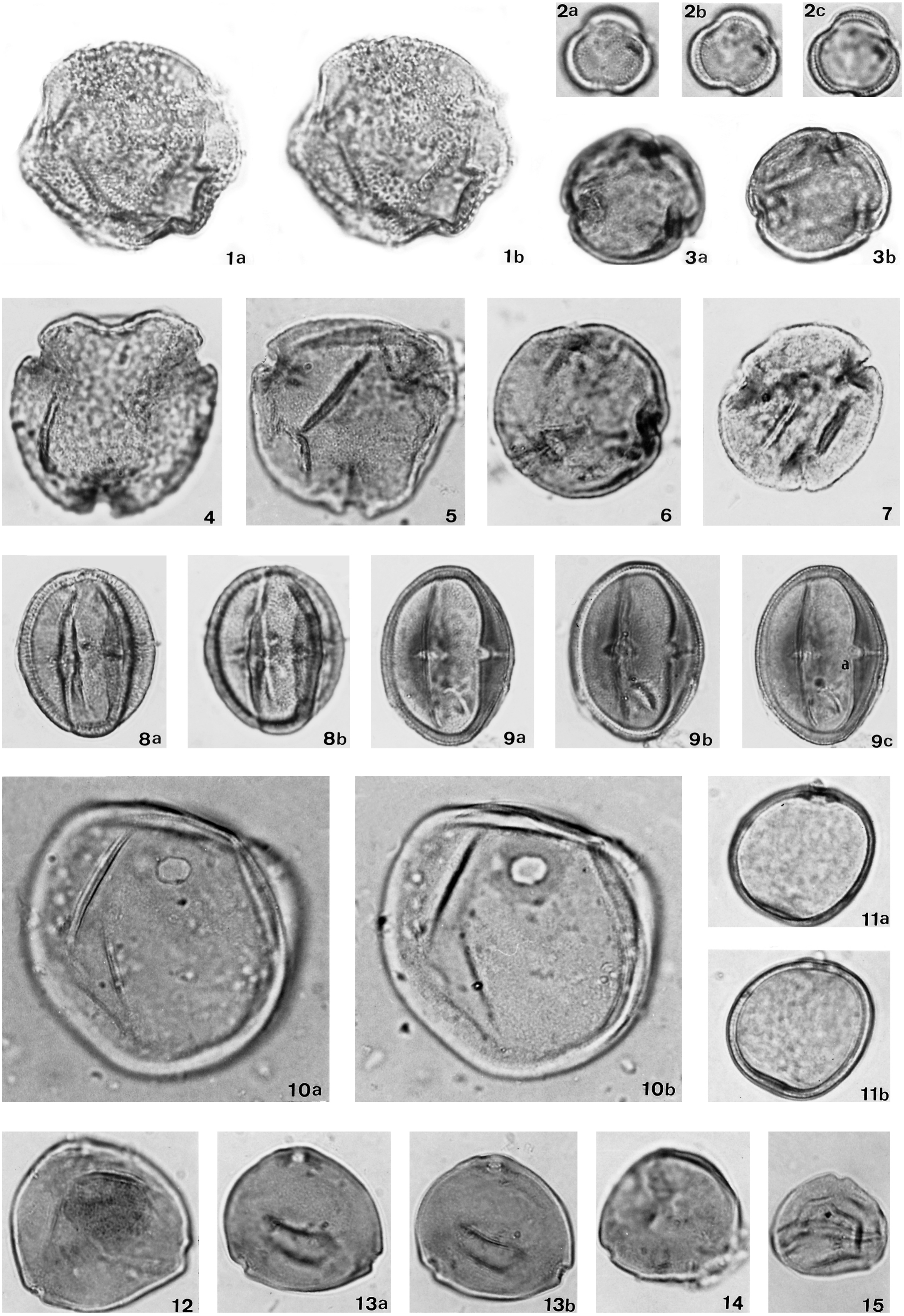
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Plate 10

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(33) ***Carpinipites carpinoides*** (Pflug in Thomson & Pflug 1953) Nagy 1985

1. Slide A7-2 (140.0/15.6)
2. Slide A34-1 (150.6/12.7)

(31) ***Trivestibulopollenites betuloides*** Pflug in Thomson & Pflug 1953

3. Slide A37-2 (137.1/16.6)

8a,b. Slide A7-2 (152.9/5.6)

(30) ***Triporopollenites rhenanus*** (Thomson in Potonié, Thomson & Thiergart 1950) Thomson in Thomson & Pflug 1953

4. Slide A33-2 (146.3/15.0)

(102) ***Intratriporopollenites pseudoinstructus*** Mai 1961

5a,b. Slide A40-1 (147.1/13.5)

(29) ***Triatriopollenites bituitus*** (Potonié 1931) Thomson & Pflug 1953

6. Slide A40-1 (144.7/15.5)
7. Slide A34-1 (152.5/14.7)

(101) ***Intratriporopollenites instructus*** (Potonié 1931) Thomson & Pflug 1953

9. Slide A50-1 (144.6/5.2)
10. Slide A7-1 (143.0/14.8)

(103) ***Lonicerapollis gallwitzii*** Krutzsch 1962

11. Slide A18-2 (138.0/16.5)

(106) ***Slowakipollis elaeagnoides*** Krutzsch 1962

12. Slide B23-1 (138.9/7.9)

(105) ***Slowakipollis cechovici*** (Pacltová 1958) Krutzsch 1962

13. Slide A7-2 (139.8/5.5)

(104) ***Sapindaceidites concavus*** Wang 1978

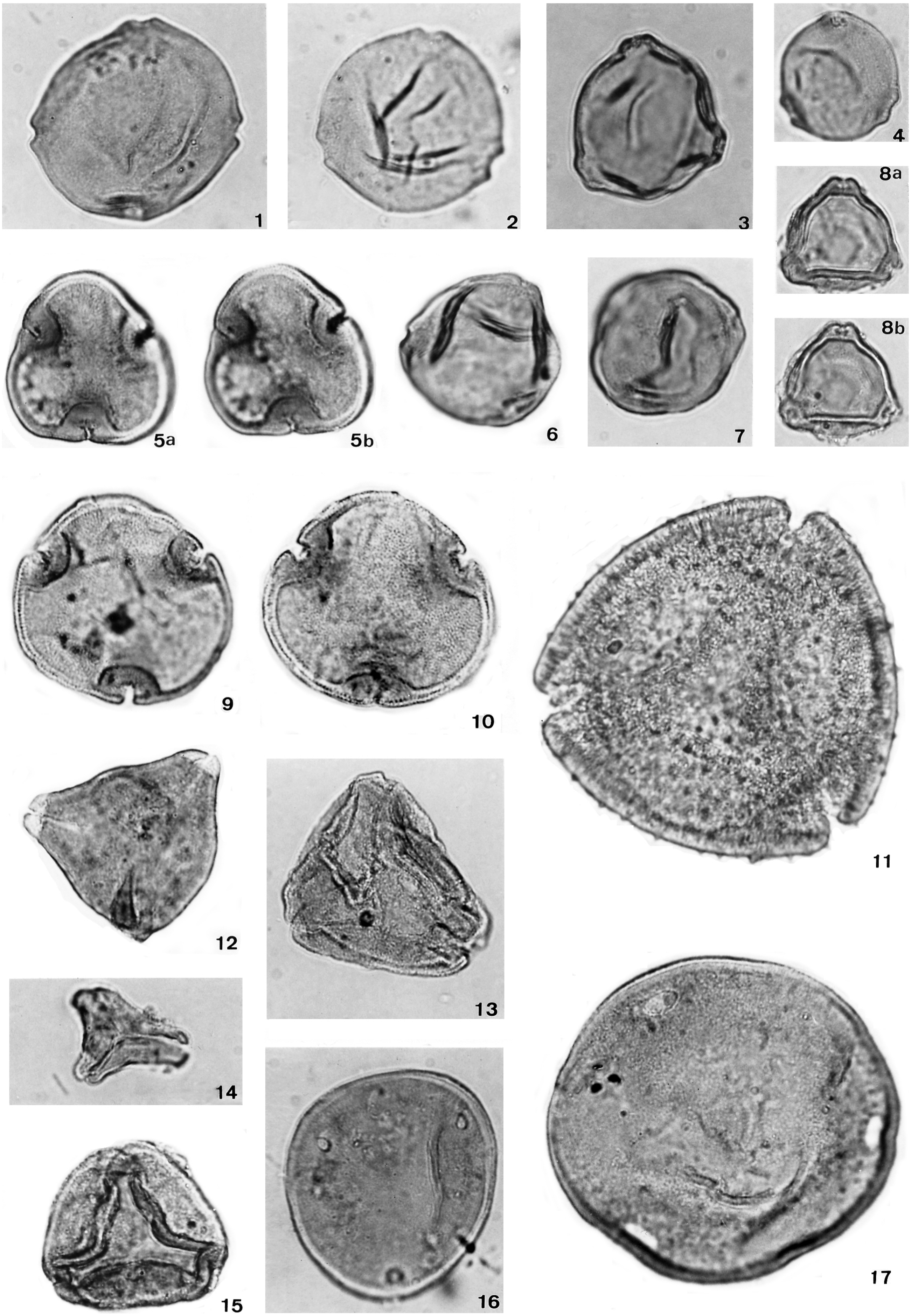
14. Slide A35-1 (141.2/ 23.4)

(100) ***Hemitrapapollenites medius*** (Guan 1985) Liu 1986

15. Slide B12-2 (154.8/13.7)

(26) ***Caryapollenites simplex*** (Potonié 1931) Raatz 1937 ex Potonié 1960

16. Slide A7-1 (144.3/10.5)
17. Slide A30-1 (146.7/16.0)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17

Plate 11

(×1000)

(47) ***Zelkovaepollenites potoniei*** Nagy 1969

1. Slide A7-1 (137.1/20.0)
2. Slide A33-2 (156.8/7.0)

(48) ***Zelkovaepollenites thiergartii*** Nagy 1969

3. Slide A7-2 (138.2/6.0)
4. Slide A33-2 (142.8/6.6)

(46) ***Ulmipollenites undulosus*** Wolff 1934

5a,b. Slide A33-2 (149.8/10.5)
6. Slide A33-2 (137.2/19.6)
7. Slide A33-2 (138.7/19.6)

(49) ***Zelkovaepollenites verrucatus*** ssp. ***minor*** (Thiele-Pfeiffer 1980) comb. nov.

8. Slide A34-1 (137.6/10.6)
9. Slide A33-2 (135.1/7.3)
10a,b. Slide A33-2 (147.2/6.9)

(44) ***Pterocaryapollenites stellatus*** (Potonié 1931) Thiergart 1937

11a,b. Slide A7-1 (137.7/14.4)
14a,b. Slide A30-1 (135.7/16.7)

(32) ***Alnipollenites verus*** Potonié 1931

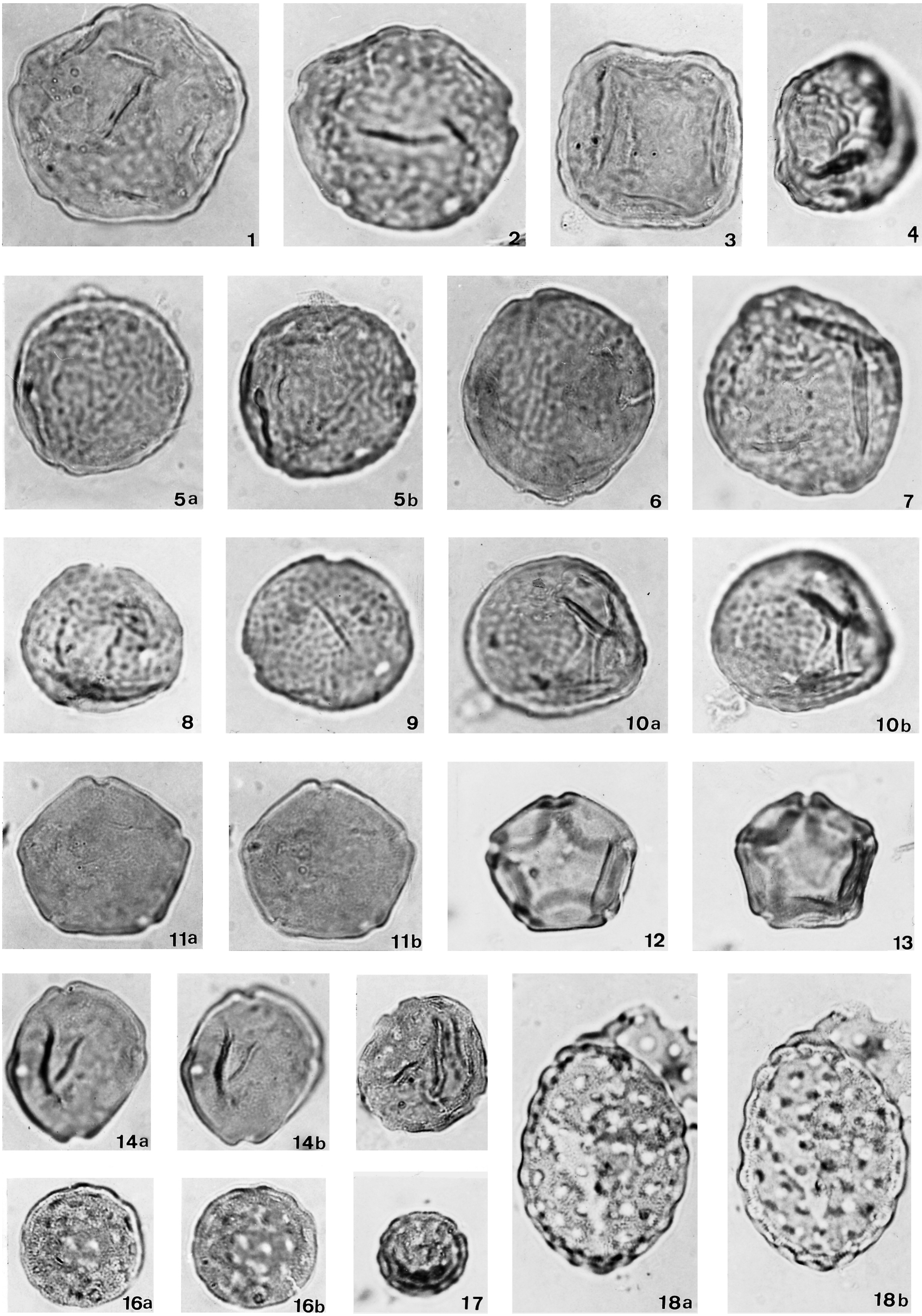
12. Slide A34-1 (151.9/13.9)
13. Slide A34-1 (153.5/12.7)

(37) ***Chenopodipollis multiplex*** (Weyland & Pflug 1957) Krutzsch 1966

15. Slide A30-1 (143.6/7.0)
16a,b. Slide A35-1 (143.6/7.7)
17. Slide A35-1 (151.9/10.1)

(36) ***Chenopodipollis maximus*** (Nagy 1969) comb. nov.

18a,b. Slide A46-1 (145.8/4.0)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14a
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16a
16b
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18a
18b

Plate 12

(×1000)

(40) ***Periporopollenites orientaliformis*** (Nagy 1969) comb. nov.

1a,b. Slide A7-2 (139.2/18.7)
4. Slide A33-2 (147.1/3.1)

(37) ***Chenopodipollis multiplex*** (Weyland & Pflug 1957) Krutzsch 1966

2a,b. Slide A35-1 (134.0/10.6)

(45) ***Punctioratipollis ludwigii*** Krutzsch 1966

3a,b. Slide A30-1 (130.7/4.9)

(39) ***Periporopollenites formosanaeformis*** (Nagy 1969) comb. nov.

5a,b. Slide A33-2 (133.2/17.0)
6. Slide A24-2 (144.6/17.2)

(41) ***Periporopollenites styracifluaeformis*** (Nagy 1969) comb. nov.

7. Slide A7-2 (152.7/16.9)
8. Slide A7-2 (152.4/18.5)

(108) ***Lymingtonia rhetor*** Erdtman 1960

9a,b. Slide A6-1 (133.6/22.5)

(42) ***Persicarioipollis franconicus*** Krutzsch 1962

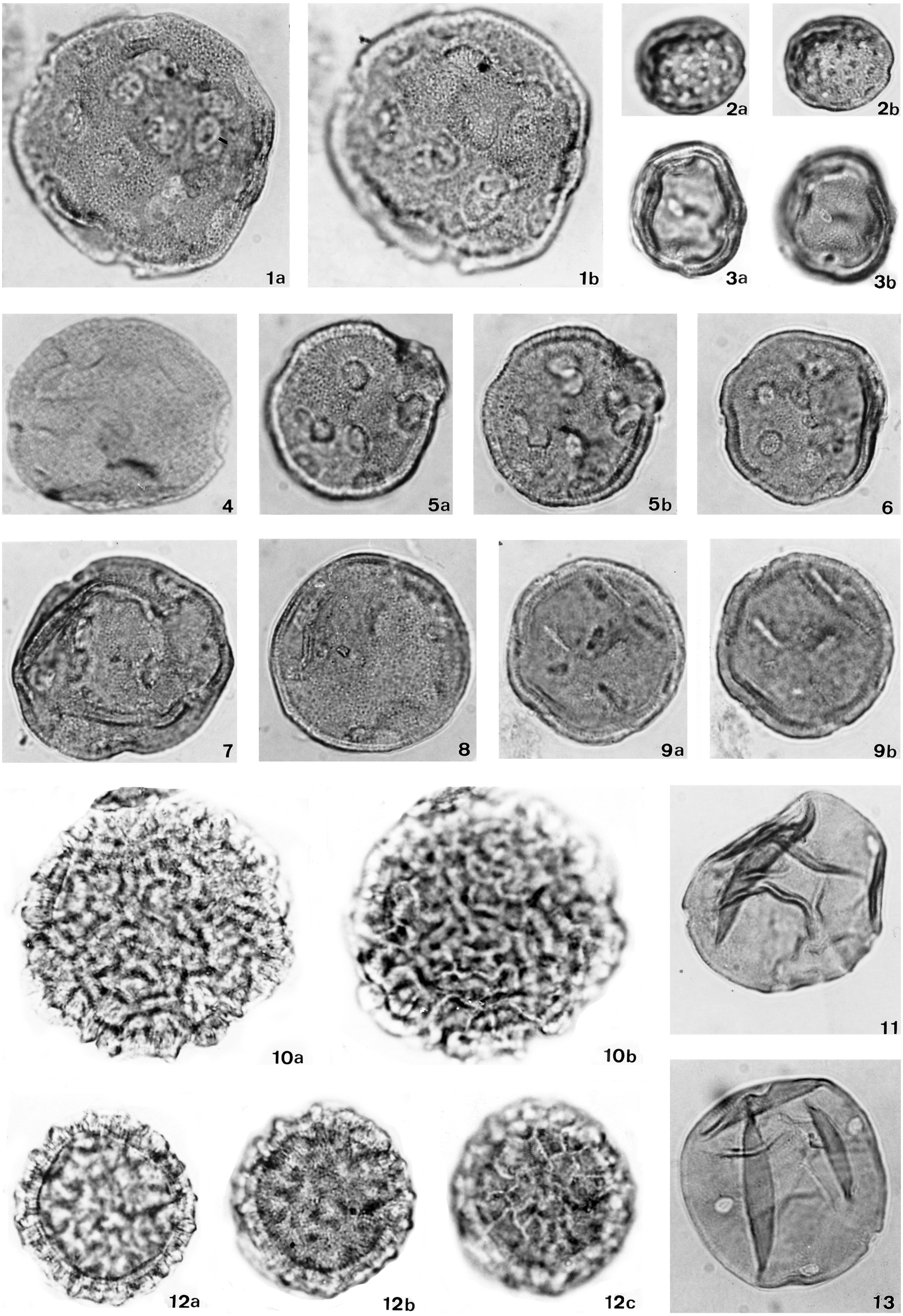
10a,b. Slide A7-2 (146.4/7.7)

(38) ***Juglandipollis juglandoides*** Kohlman-Adamska in Ziembińska-Tworzydło et al. 1994

11. Slide A28-2 (154.3/5.1)
13. Slide A37-1 (141.3/17.9)

(43) ***Persicarioipollis welzowense*** Krutzsch 1962

12a–c. Slide A7-2 (142.3/8.9)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