PALYNOLOGICAL STUDIES ON THE INTERCALATED SEDIMENTS OF THE YEMEN VOLCANICS NEAR SANA'A

by

N. M. ABOUL ELA and M. KEDVES

Department of Geology, Cairo University, Cairo, Egypt, and Department of Botany J. A. University, Szeged, Hungary

(Received: 1st March, 1987)

Abstract

On the basis of our palynological results a complex reworking during the sedimentation process of the Yemen volcanics near Sana'a was established. As regards the geological age, the sporomorphs may be grouped as follows: 1. Upper Cretaceous types, 2. Forms, which may occur in the Upper Cretaceous, but are mostly characteristic for the Lower Tertiary layers, 3. Tertiary, mostly Neogene sporomorphs, 4. Pliocene or Plio-Pleistocene forms. In this way the age of the continental intercalated sediments are Upper Neogene, probably Plio-Pleistocene. From palaeophytogeographical point of view some so-called European Upper Senonian and Tertiary taxa (Normapolles, saccate gymnosperm pollen grains) are worth of mentioning.

Introduction

The palynological investigation was carried out on seven surface samples collected from the continental sediments intercalated in the Yemen volcanics. The studied section is located about 4 km of Sana'a, along the Sana'a-Wadi Zahr asphaltic road (Fig. 1).

Stratigraphically, at the end of the Paleocene Epoch, series of volcanic tuffs and lavas of different composition have been formed covering the whole of the intensive eroded surface of the Medj-Zir Formation. These volcanic rocks, covering about a quarter of the whole Yemen, are known as Yemen volcanics (GROLIER and OVERSTREET, 1976). The Yemen volcanics are considered the most characteristic of the country. Indeed, almost the whole of the central and southern plateau of Yemen consist mainly of rocks related to these volcanics.

The Yemen volcanics are made up mainly of lava flows alternated with basalt, andesite, trachyte and varicoloured tuffs, with maximum thickness reaching about 1200 m (GEUKENS, 1966).

During the period in which these Yemen volcanics formed there were intervals during which series of continental sediments have been formed. These sediments, attaining a thickness of a few meters, consist mainly of fresh water shales and clays, fossiliferous in parts and sometimes contain bitumenous beds and plant remains. In some places these sediments are formed of paleosol, generally lateritic. These intercalated sediments are

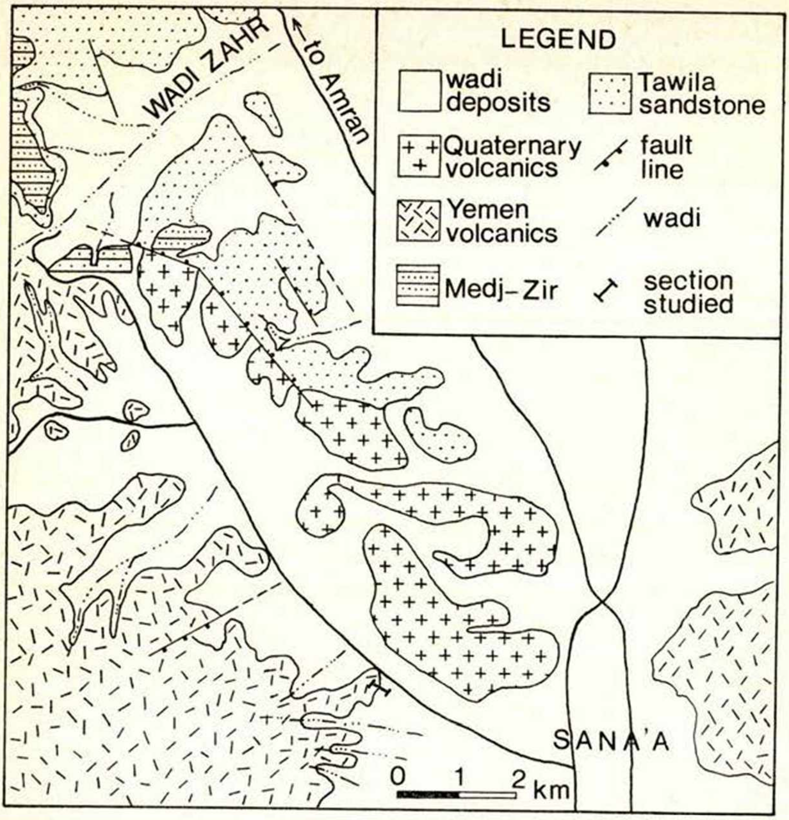

Fig. 1. Geological map of the area NW of Sana'a showing the location of the studied section

fossiliferous with fresh water gastropods, pelecypods and ostracods suggesting Oligocene-Miocene age (MORRIS, of the Arabian American Oil Co., GEUKENS, 1966). The Yemen volcanics probably started toward the end of the Cretaceous but become more intense and extensive during the Tertiary (GEUKENS, 1966).

The present work is devoted to determining, as far as possible, the exact stratigraphic position of these volcanics on the basis of the microfloral contents encountered in the intercalated sediments.

Material and Methods

The section under study measures 2.25 m and consists mainly of reddish, yellowish and greyish shales, mudstones and massive kaolinitic claystone, fossiliferous with fresh water lamellibranchs, gastropods and plant remains (Fig. 2.). The preparation of the samples followed the method pub-

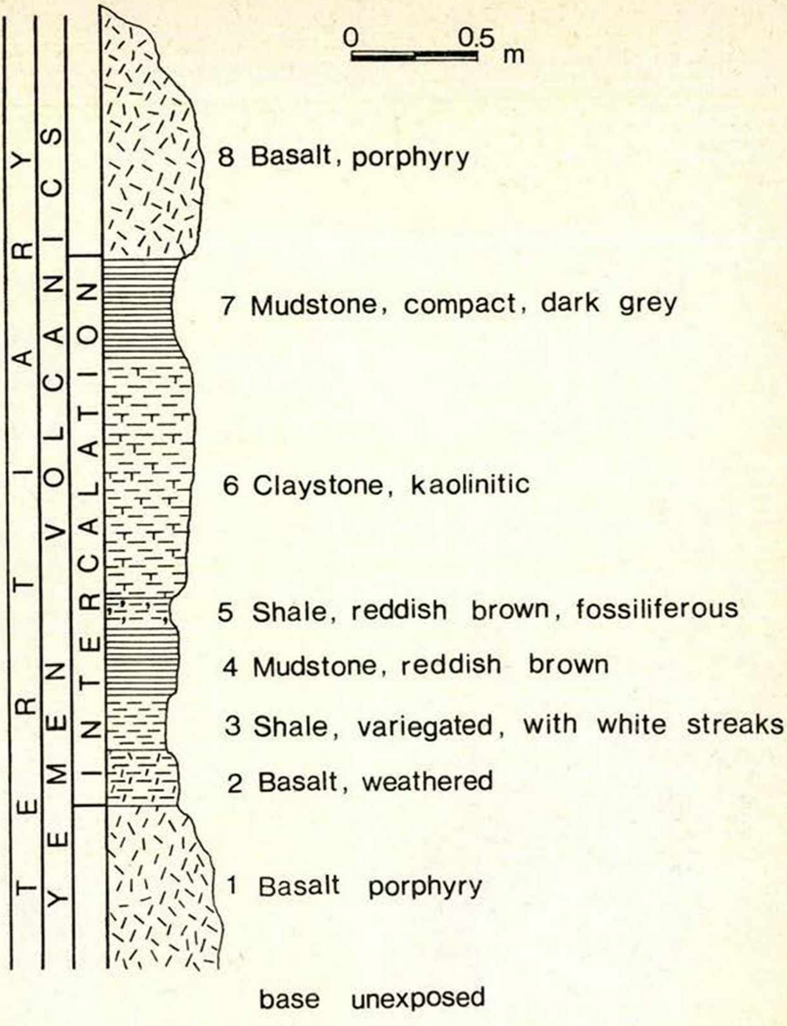

Fig. 2. Columnar section of the intercalated series

lished by KEDVES (1986). In this way the material was soaked in water for 24 hours. The treatment is made with HCl, when the piece of sediment becomes completely homogeneous it was washed with water. The material was centrifuged, then the organic material separated by $ZnCl_2$ solution of 1.89 to 2 specific weight. The $ZnCl_2$ solution comprising the organic matter is thoroughly washed after being strongly diluted. Finally the material is treated with HF, after washing the organic material was mounted in glycerine jelly hydrated in 39.6%. The slides are deposited in the collection of the Department of Botany, J. A. University, Szeged, Hungary.

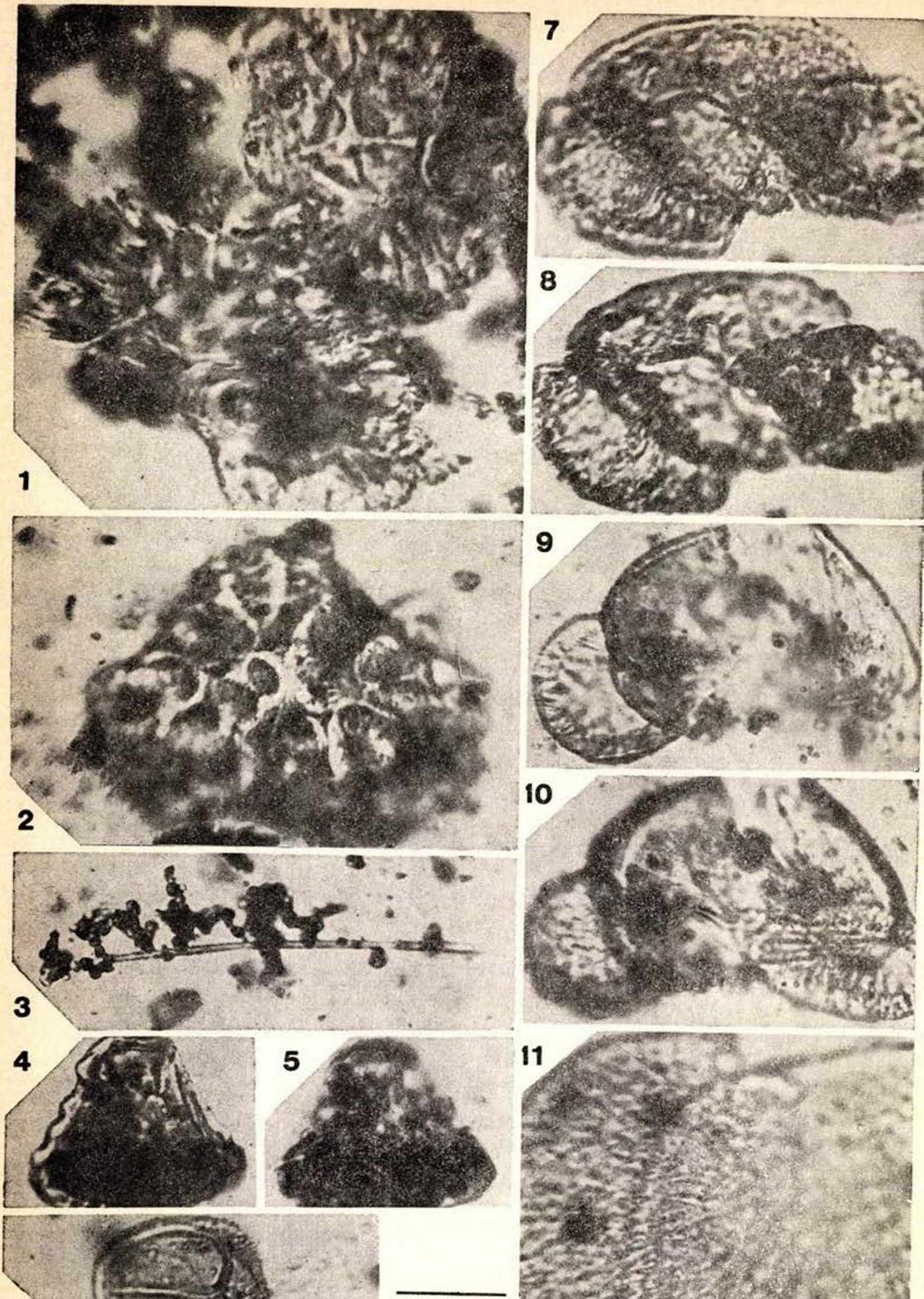
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PLATE 1.

Fig. 1. *Botryococcus braunii* KÜTZ. slide: J – 2 – 5; cross-table number: 8.4/106.3.

Fig. 2. *Botryococcus braunii* KÜTZ., slide: J – 3 – 3; cross-table number: 5.3/108.7.

Fig. 3. Conidiophora and conidia, slide: J – 5 – 14; cross-table number: 16.3/110.4.

Figs. 4, 5. *Favoisporis concavus* E. NAGY 1963, slide: J – 4 – 7; cross-table number: 5.0/104.1.

Fig. 6. *Brandenburgisporis tenera* W. KR. 1962, slide: J – 2 – 5; cross-table number: 15.0/112.7.

Figs. 7, 8. *Pityosporites labdacus* (R. POT. 1931b) TH. et PF. 1953 subfsp. labdacus, Abietaceae, Pinus, slide: J – 2 – 14; cross-table-number: 15.0/112.7.

Figs. 9, 10. *Pityosporites longus* (E. NAGY 1985) n. comb., slide: J – 3 – 1; cross-table number: 8.6/112.6.

Fig. 11. *Piceapollenites tobolicus* (PANOVA 1966) E. NAGY 1985, slide: J – 2 – 20; cross-table number: 19.4/101.3.

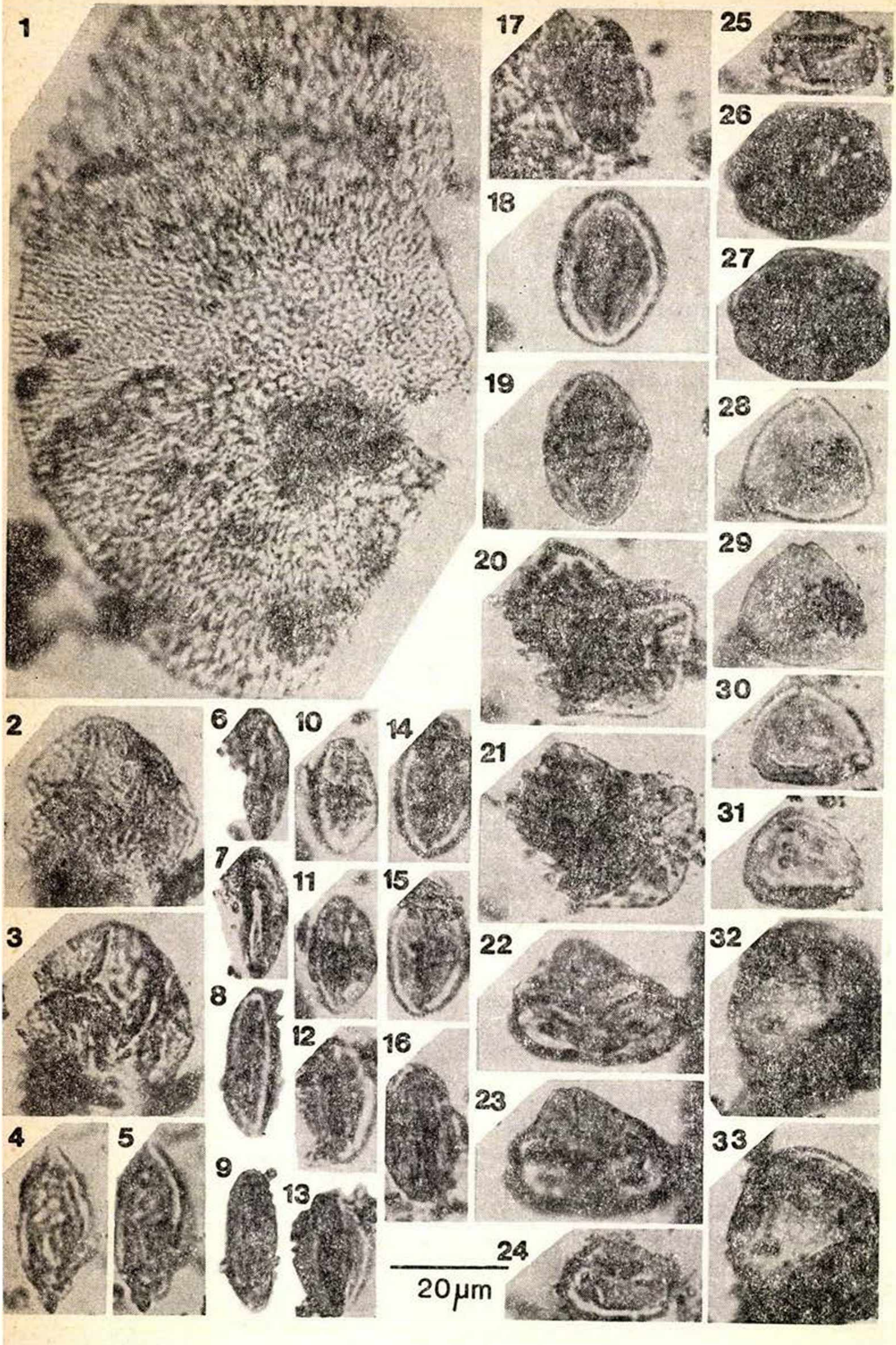
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PLATE 2.

Fig. 1. *Piceapollenites tobolicus* (PANOVA 1966) E. NAGY 1985, slide: J – 2 – 20; cross-table number: 19.4/101.3.

Figs. 2, 3. *Cupressacites hiatipites* (WODEH. 1933) W. KR. 1971, Taxodiaceae v. Cupressaceae, slide: J – 2 – 19; cross-table number: 12.7/107.8.

Figs. 4, 5. *Cycadopites cycadioides* (ZAKL. 1957) KDS. 1968, Cycadaceae, slide: J – 3 – 14; cross-table number: 13.1/109.9.

Figs. 6, 7. *Cupuliferoidaepollenites liblarensis* (THOMS., in POT., THOMS. et THIERG. 1950) R. POT. 1960, Fagaceae v. Leguminosae, slide: J – 2 – 13; cross-table number: 3.5/115.4.

Figs. 8, 9. *Cupuliferoidaepollenites liblarensis* (THOMS., in POT., THOMS. et THIERG. 1950) R. POT. 1960, Fagaceae v. Leguminosae, slide: J – 2 – 13; cross-table number: 3.5/115.4.

Figs. 10, 11. *Scabratricolpites hungaricus* KDS. 1978, slide: J – 2 – 12; cross-table number: 7.5/102.6.

Figs. 12, 13. *Scabratricolpites hungaricus* KDS. 1978, slide: J – 2 – 14; cross-table number: 12.3/119.0.

Figs. 14, 15. *Cupuliferoipollenites pusillus* (R. POT. 1934) R. POT. 1960, Fagaceae, slide: J – 2 – 17; cross-table number: 20.2/116.6.

Figs. 16, 17. *Cupuliferoipollenites pusillus* (R. POT. 1934) R. POT. 1960, Fagaceae, slide: J – 3 – 14; cross-table number: 17.1/107.4.

Figs. 18, 19. *Fususpollenites fusus* (R. POT. 1934) KDS. 1978, slide: J – 2 – 16; cross-table number: 16.8/108.2.

Figs. 20, 21. *Striatricolporites solé de portai* (KDS. 1965) KDS. 1978, Fabaceae, slide: J – 3 – 10; cross-table number: 15.4/115.4.

Figs. 22, 23. *Semioculopollis croxtonae* KDS. 1979, slide: J – 2 – 21; cross-table number: 20.7/103.7.

Figs. 24, 25. *Engelhardtioidites microcoryphaeus* (R. POT. 1931a) R. POT. slide: J – 3 – 16; cross-table number: 15.3/101.7.

Figs. 26, 27. Cf. Normapolles gen. et sp. indet., slide: J – 4 – 3; cross-table number: 2.9/117.3.

Figs. 28, 29. *Labraferoidaepollenites neerlandicus* (KDS. et HERNGR. 1980) n. comb., slide: J – 4 – 6; cross-table number: 15.5/106.7.

Figs. 30, 31. *Labraferoidaepollenites neerlandicus* (KDS. et HERNGR. 1980) n. comb., slide: J – 4 – 18; cross-table number: 10.9/107.4.

Figs. 32, 33. *Graminidites neogenicus* W. KR. 1970, Gramineae, slide: J – 2 – 13, cross-table number: 9.5/112.3.

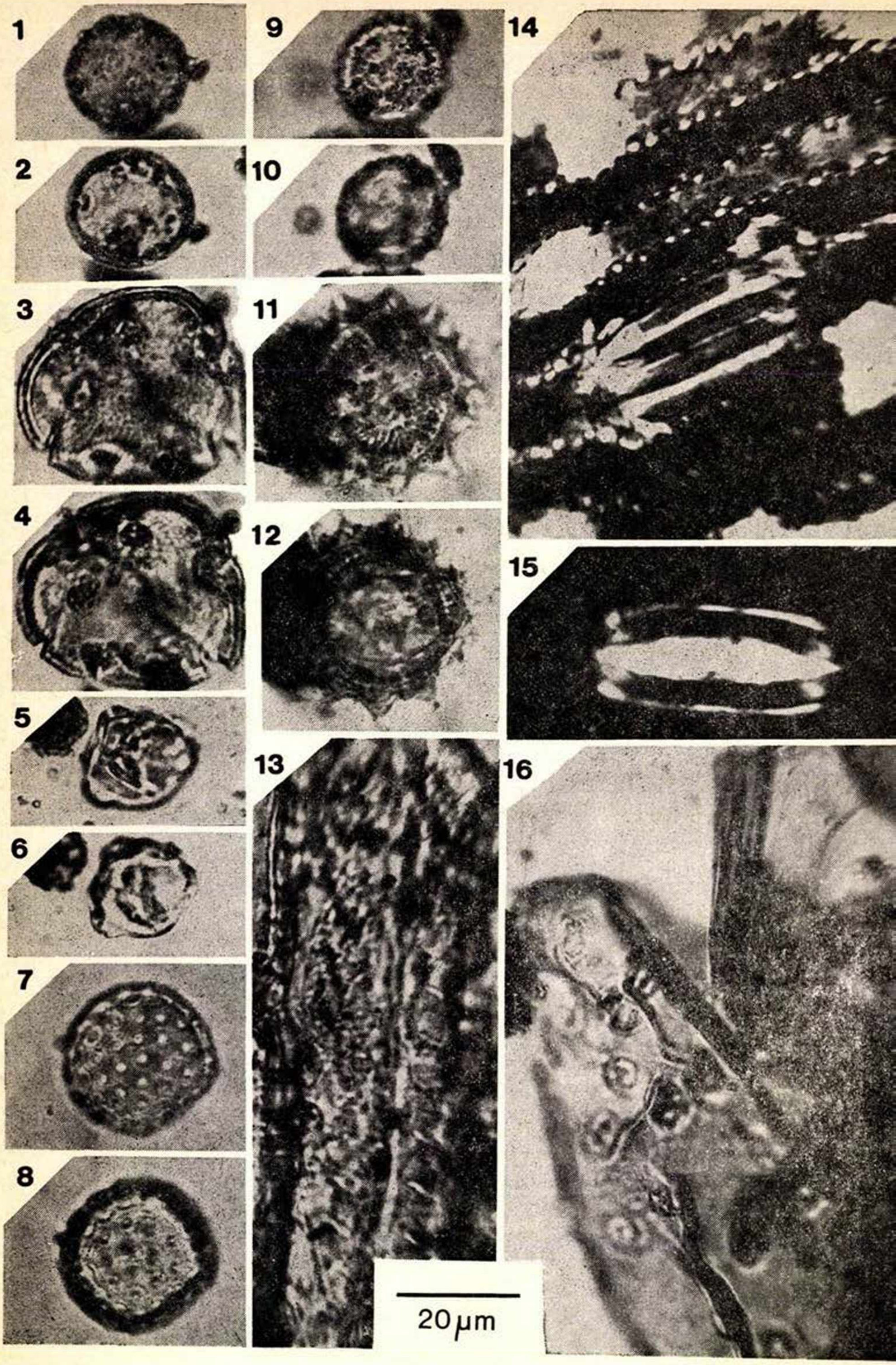
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PLATE 3.

Figs. 1, 2. *Plantaginacearumpollis miocaenicus* E. NAGY 1963, Plantaginaceae, slide: J – 2 – 21; cross-table number: 8.9/106.5.

Figs. 3, 4. *Intratriporopollenites insculptus* MAI 1961, Tiliaceae, slide: J – 3 – 15; cross-table number: 5.9/117.8.

Figs. 5, 6. *Trivestibulopollenites betuloides* PF. 1953, Betulaceae, Betula, slide: J – 3 – 1; cross-table number: 16.8/107.7.

Figs. 7, 8. *Chenopodiipollis krutzschii* KDS. 1981, Chenopodiaceae, slide: J – 2 – 8; cross-table number: 6.1/116.6.

Figs. 9, 10. *Caryophyllidites barakatii* KDS. 1981. 1981, Caryophyllaceae, slide: J – 2 – 5; cross-table number: 21.2/103.3.

Figs. 11, 12. *Tubulifloridites macroechinatus* (TREV. 1967) E. NAGY 1985, Compositae, slide: J – 3 – 17; cross-table number: 7.9/102.6.

Fig. 13. Gymnosperm secondary wood remnant, slide: J – 3 – 13; cross-table number: 9.9/103.7.

Fig. 14. Burnt epidermis, with Gramineae-type stoma, slide: J – 5 – 13; cross-table number: 15.0/102.7.

Fig. 15. Burnt epidermis, with Gramineae-type stoma, slide: J – 5 – 14; cross-table number: 19.8/115.4.

Fig. 16. Chitinous Foraminiferae shell, slide: J – 2 – 13; cross-table number: 15.7/108.7.

Results

In general, the samples are not rich in sporomorphs. The qualitative data may be summarized in the following groups:

1. From ecological point of view the following is important:
Botryococcus braunii KÜTZ (Plate 1. figs. 1, 2)
Conidiophora and conidia resembling to those of recent *Botrytis cinerea* (Plate 1, fig. 3)
Chitinous Foraminiferae shells (Plate 3, fig. 16)

The importance of the *Botryococcus*, which is a peculiar algue type was emphasized in several publications. The oil shale was formed from the remnants of the colonies of this algue. Its ecologic claim is well know, may correspond to the water of the vulcanic crater lakes. It must be emphasized that these microfossils may also be reworked. Worth of mentioning are the TEM results of the Upper Tertiary colonies, and the experimental studies of the molecular structure of the wall (KEDVES, 1983, and in print). The morphotype of conidiophora with conidia, which occurred in our material. (Plate 1, fig. 3) was observed during our researches (KEDVES and KÖRMÖCZI, 1985) on the microfossil and some selected inorganic element content of the Holocene mud of the Lake Vadkert (Hungary). We have established that when these fungous remnants occur in a huge mass, the spore-pollen and the other kind of plant microfossils are in general strongly destroyed. Later, these forms were observed in several pre-Quaternary spore-pollen assemblages, e. g. in the Maestrichtian of Northern Spain; DE PORTA, KEDVES, SOLÉ DE PORTA and CIVIS (1985), and in the Paleozoic sediments of Ófalu, Hungary; SZEDERKÉNYI and KEDVES (unpublished). The chitinous shells of Foraminiferae (Plate 3, fig. 16) refer to salt water condition.

2. Upper Cretaceous angiosperm pollen types

Semioculopollis croxtonae KDS. 1979 (Plate 2, figs. 22,23)
Cf. *Normapolles* gen. et sp. indet. (Plate 2, figs. 26,27)
Labraferoidaepollenites neerlandicus (KDS. et HERNGR. 1980) n. comb. (Plate 2, figs. 28–31)
Basionym: 1980, KEDVES and HERNGREEN, *Triatriopollenites neerlandicus* n. fsp., p. 533, plate XIV, figs. 25, 26.
These, few early angiosperm pollen types were described and found in the European Maestrichtian (Netherlands) and Lower Danian, Fish Clay Formation (Denmark) layers.

3. Mostly Lower Tertiary sporomorphs, which may occur in the Upper Cretaceous sediments too

Cycadopites cycadioides (ZAKL. 1957) KDS. 1968, Cycadaceae (Plate 2, figs, 4, 5)
Cupuliferoidaepollenites liblarensis (THOMS. in POT., THOMS. et THIERG. 1950) R. POT. 1960, Fagaceae v. Leguminosae (Plate 2, figs. 6–9)

Scabratricolpites hungaricus KDS. 1978 (Plate 2, figs. 10–13)

Cupuliferoidaepollenites pusillus (R. POT. 1934) R. POT. 1960, Fagaceae (Plate 2, figs. 14–17)

Fususpollenites fusus (R. POT. 1934) KDS. 1978 (Plate 2, figs, 18, 19)

Striatricolporites solé de portai (KDS. 1965) KDS. 1978, Fabaceae (Plate 2, figs, 20, 21)

4. Tertiary, mostly Neogene sporomorphs

Favoisporis concavus E. NAGY 1963a (Plate 1, figs. 4, 5)

Brandenburgisporis tenera W. KR. 1962 (Plate 1, fig. 6)

Cupressacites hiatipites (WODEH. 1933) W. KR. 1971, Taxodiaceae v. Cupressaceae (Plate 2, figs, 2, 3)

Pityosporites labdacus (R. POT. 1931b) TH. ET PF. 1953 subfsp. *labdacus*, Abietaceae, Pinus (Plate 1, figs. 7, 8)

Pityosporites longus (E. NAGY 1985) n. comb. (Plate 1. figs, 9, 10)
Basionym: 1985, E. NAGY, *Pinuspollenites longus* n. sp., p. 129/130, plate LVIII. figs. 2–6.

Piceapollenites tobolicus (PANOVA 1966) E. NAGY 1985 (Plate 1, fig. 11, plate 2, fig. 1)

Engelhardtioidites microcoryphaeus (R. POT. 1931a) R. POT. 1960 (Plate 2, figs. 24, 25)

Plantaginacearumpollis miocaenicus E. NAGY 1963b, Plantaginaceae, Plantago (Plate 3, figs. 1, 2)

Intratriporollenites insculptus MAI 1961, Tiliaceae (Plate 3, figs. 3, 4)

Trivestibulopollenites betuloides PF. 1953, Betulaceae, Betula (Plate 3, figs. 5, 6)

Graminidites neogenicus W. KR. 1970, Gramineae (Plate 2, figs. 32, 33)

5. Pliocene or Plio-Pleistocene forms

Chenopodiipollis krutzschii KDS. 1981, Chenopodiaceae (Plate 3, figs. 7, 8)

Caryophyllidites barakatii KDS. 1981 (Plate 3, figs. 9, 10)

Tubulifloridites macroechinatus (TREV. 1967) E. NAGY 1985 (Plate 3, figs. 11, 12)

6. Plant tissue remnants

Gymnosperm secondary wood remnant, tracheids with developed type pits (Plate 3, fig. 13)

Burnt epidermis, with Gramineae-type stoma (Plate 3, figs. 14, 15)

On the basis of the quantitative data we can establish the following:

It is well shown in fig. 3 that the lower part of the sediments studied is relatively rich in sporomorphs. In samples N° 7 and 5, there are Norma-

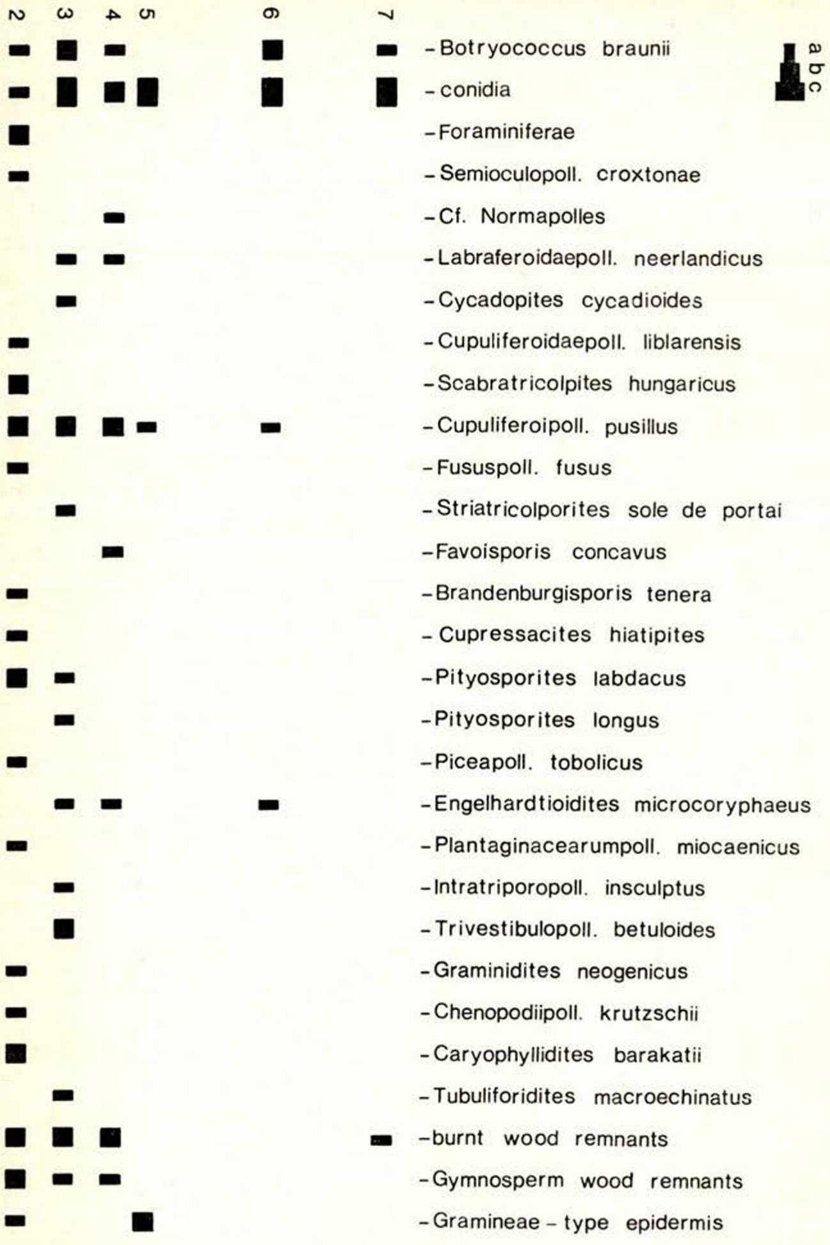

Fig. 3. Diagram of the plant microfossils. a = rare, b = common, c = dominant

polles taxa, referring without doubt to an Upper Cretaceous reworking. In the lowest sample (No 7) occur only chitinous Foraminiferae shells too, indicating that one part of the rebedded sediments was of marine origin. The so-called old Tertiary pollen grains with relative abundance of Longaxones indicate a semiterrestrial swamp ecology. For the Neogene material we can suppose a Cupressaceae-Pteridophyta swamp ecology, with Gramineae, and on the highland Gymnosperm wood with *Pinus* and *Picea*. The few, young Tertiary or Pliocene-Pleistocene angiosperm pollen grains, of the Chenopodiaceae, Caryophyllaceae and Compositae, refer firstly to an ingression of the coastal swamp. It seems that the tissue remnants, in particular the epidermis of Gramineae-type stoma, and the secondary wood remnants with modern pitting are important in the determination of the age of the intercalated sediments. The microfossil content of sample No 6 is essentially the same, only the lack of the Normapolles is worthy of mention. In sample No 4 there are very few plant microfossils, the conidia are dominant, the Gramineae-type epidermis refer only to an Upper Tertiary age. The samples of the upper part of the series of the sediments studied contain in a huge mass conidia, Botryococcus algue and very few pollen grains.

Discussion and conclusions

1. The plant microfossil assemblages of the studied samples of the Yemen volcanics intercalated series near Sana'a refer to an Upper Tertiary age, with reworking of different ages (Upper Cretaceous, Paleogene, Lower Neogene). From ecological point of view important microfossils e. g. the *Botryococcus* algue, and the chitinous shells of Foraminiferae may also be reworked. In connection with this we cite the publication of Wilson (1964), p. 432: "In the clays of the Mississippi River it is not uncommon to find marine microfossils along with spores and pollen of Pennsylvanian, Cretaceous, Tertiary and Recent plants." It was pointed out in several publications, that the colour, and the preservation of the reworked forms are different, we have observed this phenomenon during our investigations, too.

2. The conidia and conidiophora which we have observed in general in a mass in our samples may be the remnants of Fungi, which degrade the organic remains.

3. The Normapolles and the greatest part of the Postnormapolles is characteristic for the European Senonian and Lower Tertiary layers. We must emphasize that our data are not enough for a final palaeophytogeographical conclusion, but we can take into consideration the following; Kedves (1985), p. 124: "1. From a palaeophytogeographical point of view, in Senonian time, Madagascar is most important, because it is situated near three provinces (Aquilapollenites, Nothofagidites and Monocolpates). Therefore, a peculiar mixed pollen flora may be presumed here. 2. Further interesting areas, for palynological investigations: 2.1. Southern part of Arabia; question: is the genus *Aquilapollenites* present here together with the

so-called Gondwana elements?" It seems, that the results of further investigations on the Cretaceous and Tertiary sediments of Yemen may be very interesting and important in palaeophytogeographical respect too.

REFERENCES

De Porta, J., Kedves, M., Solé de Porta, N. y Civis, J. (1985): Palinologia del Maastrichtiense del Barranco de la Posa (Lérida, España). Problemática regional. – Rev. Inv. Geol. 40, pp. 5–28, pl. I–VII.

Geukens, F. P. M. (1966): Geology of the Arabian Peninsula, Yemen. A review of the geology of Yemen as shown as USGS miscellanous geologic investigation map 1–270A "Geologic Map of the Arabian Peninsula". – US Government Printing Office, Washington, paper 560–B., pp. 1–23.

Grolier, M. J. and Overstreet, W. C. (1976): Preliminary and simplified geologic map of Yemen Arab Republic LANDSTAT–1 image No. 1136–07012 U.S.G.S., openfile. Report Map scale 1:5000 000.

Kedves, M. (1965): Palynological investigations on the Lower Eocene layers in the surrounding country of Iszkaszentgyörgy III. – Acta Biol. Szeged 11, 1–2, pp. 33–50, pl. I–VIII.

Kedves, M. (1968): Études palynologiques des couches du Tertiaire inférieur de la Région Parisienne. III. – Pollens inaperturés, à ballonnets, polypliqués, monocolpés, disulquéa, trichotomosulqués, et proxaperturés. – Pollen et Spores 10, 2, pp. 315–334, pl. I–III.

Kedves, M. (1978): Paleogene fossil sporomorphs of the Bakony Mountains Part III. – Studia Biol. Acad. Sci. Hung. 15, pp. 1–166.

Kedves, M. (1979): Palynological investigations on sediments of the Lower Danian (Fish Clay, Denmark) I. – Acta Miner. – Petr. Szeged 24, 1, pp. 167–186, pl. I–V.

Kedves, M. (1981): Études palynologiques sur les sédiments préquaternaires de l'Egypte. Néogène I. – Grana 20, pp. 119–130.

Kedves, M. (1983): Étude paléobotanique sur les schistes pétrolifères du Tertiaire Supérieur de Hongrie. – Rev. de Micropaléont. 26, 1, pp. 48–53, pl. I–II.

Kedves, M. (1985): The present day state of Upper Cretaceous palaeophytogeography on palynological evidence. – Acta Biol. Szeged 31, 1–4, pp. 115–127.

Kedves, M. (1986): Introduction to the Palynology of Pre-Quaternary deposits Part I. – Studia Biol. Acad. Sci. Hung. 19, pp. 1–164.

Kedves, M. (in print): Dégradation expérimentale des colonies du genre Botryococcus des schistes pétrolifères du Tertiaire supérieur de Hongrie. – Acta Biol. Szeged

Kedves, M. and Herngreeg, G. F. W. (1980): Palynology of the stratotype of the Maestrichtian and the Gulpen Formation, ENCI Section, Maastricht, The Netherlands. – Pollen et Spores 22, 3–4, pp. 483–544, pl. I–XV.

Kedves, M. et Körmöczi, L. (1985): Sur les problèmes de conservation des sporomorphes dans des conditions differentes. – An. Asoc. Palinol. Leng. Esp. 2, pp. 263–271.

Krutzsch, W. (1962): Atlas der mittel- und jungtertiären dispersen Sporen- und Pollensowie der Mikroplanktonformen des nördlichen Mitteleuropas. Lief. I. Laevigate und toriate trilete Sporenformen. – VEB Deutscher Verlag der Wissenschaften, Berlin, pp. 1–108, pl. 1–46.

Krutzsch, W. (1970): Atlas der mittel- und jungtertiären dispersen Sporen- und Pollensowie der Mikroplanktonformen des nördlichen Mitteleuropas. Lief. VII. Monoporate, monocolpate, longicolpate, dicolpate und ephedroide (polyplicate) Pollenformen. – VEB Gustav Fischer Verlag, Jena, pp. 1–175, pl. 1–50.

Krutzsch, W. (1971): Atlas der mittel- und jungtertiären dispersen Sporen- und Pollensowie der Mikroplanktonformen des Mikroplanktonformen des nördlichen Mitteleuropas. Lief. VI. Coniferenpollen. – VEB Gustav Fischer Verlag, Jena, pp. 1–234, pl. 1–74.

Mai, H. D. (1961): Über eine fossile Tiliaceen-Blüte und tilioiden Pollen aus dem deutschen Tertiär. – Geologie 10, BH 32, pp. 54–93, pl. IX–XIII.

NAGY, E. (1963a): Spores et pollens nouveaux d'une coupe de la briqueterie d'Eger (Hongrie). – Pollen et Spores 5, 2, pp. 397–412.

NAGY, E. (1963b): Some new spore and pollen species from the Neogene of the Mecsek Mountain. – Acta Bot. Acad. Sci. Hung. 9, 3–4, pp. 387–404, pl. I–V.

NAGY, E. (1985): Sporomorphs of the Neogene in Hungary. – Geol. Hung. 47, pp. 1–471, pl. I–CXVIII.

PANOVA, L. A. (1966): Spores and pollen grains from Lower Oligocene sediments. – In.: Andreeva, E. M. et al. (eds.), Paleopalynology III, p. 360. (Russian)

POTONIÉ, R. (1931a): Zur Mikroskopie der Braunkohlen. Tertiäre Blütenstaubformen. 1. Mitt. – Z. Braunkohle 1931, pp. 225–233, pl. 2.

POTONIÉ, R. (1931b): Pollenformen aus tertiären Braunkohle. – Jb. Preuss. Geol. Landesamt. 52, pp. 1–7.

POTONIÉ, R. (1934): Zur Mikrobotanik des eozänen Humodils des Geiseltales. – Arb. aus Inst. Palaobotanik und Petrogr. Brenngesteine 4, pp. 25–125, pl. 1–6.

POTONIÉ, R. (1960): Synopsis der Gattungen der Sporae dispersae III. Teil: Nachträge Sporites, Fortsetzung Pollenites. Mit Generalregister zu Teil I–III. – Beih. Geol. Jb. 39, pp. 1–189, pl. 1–9.

POTONIÉ, R., THOMSON, P. W. und THIERGART, F. (1950): Zur Nomenklatur und Klassifikation der Sporomorphae (Pollen und Sporen). (Zur Geologie der rheinischen Braunkohle 1). – Geol. Jb. für das Jahr 1949 65, pp. 35–70, pl. 1–3.

THOMSON, P. W. und PFLUG, H. D. (1953): Pollen und Sporen des mitteleuropäischen Tertiärs. – Palaeontographica B, 94, 1–4, pp. 1–138, pl. 1–15.

TREVISAN, L. (1967): Pollini fossili del Miocene superiore nei tripoli del Gabbro (Toscana). – Palaeontographia Italica 62, pp. 1–73, pl. I–XXXVI.

WILSON, L. R. (1964): Recycling, stratigraphic leakage, and faulty techniques in Palynology. – Grana Palynologica 5, 3, pp. 425–436.

WODEHOUSE, R. P. (1933): Tertiary pollen. II. The oil shales of the Eocene Green River Formation. – Bull. Torr. Bot. Club 60, pp. 479–524.

ZAKLINSKAYA, E. D. (1957): Stratigraphic value of the Cenozoic gymnospermous pollen of the Pavlodarsk stretch of the Irtysh river and the northern Aral Coast. – Trud. Geol. Inst. URSS, 6, pp. 1–184, pl. I–XVII. (Russian)