The middle Miocene palynofloras of the Salihpaşalar lignite mine (Yatağan Basin, southwest Anatolia): environmental characterisation and comparison with palynofloras from adjacent basins

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Received: 23 December 2017 / Revised: 23 March 2018 / Accepted: 29 May 2018 / Published online: 4 September 2018

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Abstract

As the third part of an ongoing investigation of middle Miocene palynofloras in the Yatağan Basin (YB), southwestern Anatolia, the palynofloras of the Salihpaşalar lignite mine in the main YB were studied. Seven types of algal spores, aplanospores/zygospores or cysts, six types of lycophyte and fern spores, 12 types of gymnosperm pollen and 90 types of angiosperm pollen were identified. Of a total of ca. 140 plant taxa described from the YB, over 10% are confined to the Salihpaşalar assemblage. Differences between coeval palynofloras of the Sekköy Member might reflect changing or prograding depositional environments. A number of rare accessory taxa reflect these local differences: *Pilularia*, *Valeriana*, *Drosera* and *Persicaria* aff. *amphibia* only occur at Salihpaşalar and are typical of shallow water or temporary ponds associated with a lake shore. Apart from this, all the palynofloras, originating from the lignite seams and overlying limnic limestones (uppermost Turgut and Sekköy Member), of the YB are strongly indicative of extensive woody vegetation with a dominance of diverse Fagaceae and Pinaceae. In addition, a list comparing the well-documented YB palynomorphs to morphologically similar palynomorphs of published late early to middle Miocene plant assemblages of western Anatolian was compiled. Such a comparison reveals that in many instances different taxon names have been used to denote the same taxa. Hence, resolving these synonymies is a prerequisite of any meaningful comparison of palynofloras in the region.

Keywords Neogene · Western Anatolia · Dispersed pollen · Scanning electron microscopy · Botanical nomenclature · Artificial nomenclature

Introduction

High tectonic activity in western Anatolia during the late Cenozoic associated with the collision of the Arabian and Anatolian plates resulted in orogeny, volcanic activity and basin formation (Rögl

1999; Popov et al. 2004; van Hinsbergen and Schmid, 2012). In southwestern Anatolia, the Denizli, Söke and Yatağan Basin (YB) among others formed with the onset of the Miocene subsidence (Alçiçek 2010). Age correlation of these Miocene fault-bounded basins is complicated and previously suggested ages for individual basins based on different proxies have been highly controversial. Specifically, it has been demonstrated that palynological data alone are not sufficient to reliably infer the age of a particular basin (Bouchal et al. 2016). Examples from western Anatolia for conflicting ages inferred from palynological data and radiometric dating include the Soma Basin, for which Akgün et al. (2007) suggested a middle Miocene age whereas radiometric dates from Ersoy et al. (2014) suggest an early Burdigalian age, the Gördes Basin, for which Akgün et al. (2007) suggested an early to middle Serravallian age, while Purvis et al. (2005) based on radiometric dates inferred a late Aquitanian to early Burdigalian age based on radiometric dates, and the Bigadiç Basin, for which Akyol and Akgün (1990) inferred a middle to earliest late Miocene age, while Erkül et al. (2005) suggested an early Burdigalian age, based, again, on radiometric dating. Complementary data, such as

This article is a contribution to the special issue "Taking the Orient Express? The role of Anatolia in mediterranean Neogene palaeobiogeography".

Electronic supplementary material The online version of this article (<https://doi.org/10.1007/s12549-018-0345-0>) contains supplementary material, which is available to authorized users.

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vertebrate fossils or radiometrically dated layers, are hence of utmost importance for reliably inferring the age of a fossil locality.

Another issue that hampers the comparison of Neogene sedimentary basins in western Anatolia relates to the two concepts applied for the naming of dispersed fossil pollen and spores. A substantial number of studies have been using the artificial fossil nomenclature (strictly morphology based) for palynomorphs, while in more recent publications, conventional botanical names are used more often. Therefore, it may be difficult to compare studies for a particular area, potentially leading to highly redundant taxon lists.

The present contribution is the third in a series of papers dealing with the palynology of middle Miocene (MN6–MN7/8) deposits of the upper Turgut and Sekköy Member of the Eskihisar Formation in southwestern Anatolia (Bouchal et al. 2016, 2017). Previous palynological studies have concentrated on the Eskihisar and the Tınaz lignite mines and vertebrate localities (e.g. Benda 1971; Gemici et al. 1990; Erdei et al. 2002; Akgün et al. 2007; Yavuz-Işık et al. 2011; Koç, 2017; Bouchal et al. 2016, 2017).

The present investigation focuses on the Salihpaşalar lignite mine located to the south of the main YB that was exploited for a short period between 2012 and 2015. The sections studied in previous papers and in the present paper are strongly correlated by the palynological content of the lignite seams overlying limestones and their age is well-constrained by vertebrate fossils recently identified from the main coal seam of the Eskihisar lignite mine (electronic supplementary material in Bouchal et al., 2017) and the fossil vertebrate locality Yeni Eskihisar (Sickenberg 1975; Saraç 2003; Wessels 2009; The NOW Community 2018).

In this paper, I will (i) describe palynological assemblages from a stratigraphic column at Salihpaşalar using a combined scanning electron and light microscopy approach, (ii) compare the palynological records of three lignite mines in the YB, and (iii) discuss the palaeoenvironmental signal of the palynological data from the YB palynofloras. In addition, a list comparing the well-documented YB palynomorphs to morphologically similar pollen of other late early to middle Miocene palynoassemblages of western Anatolian strata was compiled [Supplementary Material (S) 2]. This is an attempt to accommodate previous concepts of palynological nomenclature (strictly morphology based) and modern concepts of applying botanical names to palynomorphs for this region.

Materials and methods

Geological setting

The YB, Muğla, southwestern Turkey, is a southeast-trending graben, up to 50 km long and 15 km wide (Fig. 1a, b). The

basin is divided by an axial bedrock horst (metamorphic cover rocks of the Menderes Massif) in the smaller (ca 12 km long, 1 km wide, south east trending) Tınaz subbasin (Fig. 1b) and the main YB. The northern area of the main basin between Eskihisar and Turgut (west and north of Aladağ Mountain) is segregated from the southern part by a bedrock sill (Fig. 1b; Atalay 1980; Becker-Platen 1970). The Neogene basin fill is up to 600 m thick and grouped into the Eskihisar Formation (early to middle Miocene), the Yatağan Formation (late Miocene to early Pliocene), and the Milet Formation (middle to late Pliocene). The Eskihisar Formation is subdivided in Turgut Member (reddened alluvial-fan deposits followed by fluvial deposits and lignites) and Sekköy Member (limnic marls and limestones; Fig. 1c). For the present study, the type profiles of the Turgut and Sekköy members as designated by Becker-Platen (1970, p. 22 ff. and pp. 26–27) were used as reference points and the boundary placed between the two members where the change from siliciclastic (non-carbonatic) to carbonate sedimentary rocks occurs. Five lignite fields (Eskihisar field, Tınaz field, Bağyaka field, Bayır field, Turgut field) have been prospected in the YB. All economically exploited lignite seams of the YB are confined to the transition zone of the Turgut and Sekköy members of the Eskihisar Formation (Becker-Platen 1970; Inaner et al. 2008).

Age of the Salihpaşalar lignite mine section

The stratigraphic chart of the Mediterranean and Paratethyan realm has been going through several changes since the 1970s; for stratigraphic ages and ranges of Becker-Platen (1970), the updated corresponding age is provided based on the compiled stratigraphic chart of Neubauer et al. (2015). In the overview map of the YB, Becker-Platen (1970, pl. 3) assigned an area (ca 2 km long, 0.5 km wide) east of the village of Salihpaşalar to the Sekköy Member (=Sekköy Formation in Becker-Platen). Additionally, the following age constraining fossils are listed (sample localities P419, P431, P434 in Becker-Platen 1970): pulmonate gastropods—*Clausilla* sp.; Ostracoda—*Cytheromorpha zinndorfi*, *Loxoconcha granosa*, *Hemicythere folliculosa*, *Cyprideis* cf. *littoralis* → Helvet to Pannon (=middle to late Miocene age); pharyngeal teeth of cyprinids—“*Cypridopsis*” *biplanata* → Torton (=early late Miocene). Atalay (1980) reported two vertebrate fossil localities NEE of the village Salihpaşalar (Salihpaşalar-Kemikalan, Salihpaşalar-Karaağaç; both assigned to MN12, late Tortonian to early Messinian; The NOW Community 2018) and assigned the rocks of this area to the late Miocene Yatağan Formation. So far, the stratigraphic relevant animal taxa of the Salihpaşalar lignite mine have not been investigated (Serdar Mayda, personal communication 2017). The here documented palynoflora corresponds to previously reported pollen floras and leaf assemblages of the YB lignite mines (Tables 1 and 2; Bouchal et al. 2016, 2017; Güner et al. 2017); for the macro and micro floras, an age of MN6 to

Fig. 1 Geographic and regional geologic setting of the Salihpaşalar lignite mine section, Yatağan basin. **a** Map showing the geographical position of the Yatağan Basin (**b**). **b** Simplified regional geological map of the Yatağan Basin based on Atalay (1980), Becker-Platen (1970) and Inaner et al. (2008); basin subdivisions main Yatağan Basin (MYB), Tınaz subbasin (TSB), Eskihişar-Turgut area (ETA); lignite mines Salihpaşalar (A), Tınaz (B), Bağyaka (C) and Eskihişar (D). Asterisk:

vertebrate fossil localities (1) Salihpaşalar-Kemikalın (MN12) and Salihpaşalar-Karaağaç (MN12), (2) Yeni Eskihişar 1 (MN7/8). **c** Profile of the sampled Salihpaşalar mine section. The sampled section belongs to the Eskihişar Formation and includes the uppermost part of the Turgut Member, which is here considered to be of Langhian (middle middle Miocene) age

MN7/8 is proposed due to their lithostratigraphic position between the vertebrate locality Eskihişar Gallery (MN6) and the younger Yeni Eskihişar locality [MN(7)/8] (Bouchal et al. 2017; Wessels 2009). Tuff layers from the upper Sekköy Member (Yeni Eskihişar II mammal locality) produced radiometric dates of $13.2 \text{ Ma} \pm 0.35$ and 11.2 ± 0.2 (Becker-Platen et al. 1977).

The Salihpaşalar mine and other lignite mines of the YB

The Salihpaşalar open cast lignite mine is located close to the D-550 motorway, southeast of the village of Salihpaşalar (Fig. 1b) and is the southernmost part of the Bayır lignite field (Inaner et al. 2008). The main lignite seam of the Bayır lignite

Table 1 Taxa encountered in the Salihpaşalar section

Taxon	Figure (this paper)	Description (previous papers)	Occurrence
Algae			
Algal cyst indet. 1	Fig. 3j–k and S 3-Fig. 2a–c	This study	This study
Algal cyst indet. 2/ <i>Sigmopollis pseudosetarius</i>		This study	ES
Botryococcaceae			ES
<i>Botryococcus</i> cf. <i>B. braunii</i>	Fig. 3a and S 3-Fig. 1a–c		
Zygnemataceae			
<i>Spirogyra</i> sp. 1/ <i>Ovoidites lanceolatus</i>	Fig. 3a and S 3-Fig. 1d–f	[1] p. 20	ES, except S153632, S153645
<i>Spirogyra</i> sp. 2/ <i>Ovoidites microfoveolatus</i>	Fig. 3b–d and S 3-Fig. 1g–i	[2] p. 4	ES, except S153632, S153645
<i>Spirogyra</i> sp. 3/ <i>Ovoidites spriggii</i>	Fig. 3e and S 3-Fig. 1j–l	This study	S153623
<i>Spirogyra</i> sp. 4/ <i>Cycloovoidites cyclus</i>	Fig. 3f–i and S 3-Fig. 1m–o	This study	S153622, S153623
Moss, fern and fern allies spores			
Monolete spore fam. indet./ <i>Laevigatosporites haardi</i>	Fig. 3o and S 3-Fig. 2j–l	[1] p. 23; [2] p. 6	ES
Lycopodiaceae			
<i>Lycopodium</i> sp./ <i>Retiriletes annotinioides</i>	Fig. 4a–c	This study	S153622, S153627
<i>Lycopodiella</i> sp./ <i>Camarozonosporites helenensis</i>	Fig. 4d–f	This study	S153627
Selaginellaceae			
<i>Selaginella</i> sp./ <i>Echinatisporites miocenicus</i>	Fig. 4g–i	This study	S153622
Marsileaceae			
<i>Ptilularia</i> sp.	Fig. 4j–l	This study	S153623
Osmundaceae			
<i>Osmunda</i> sp./ <i>Baculatisporites nanus</i>	Fig. 3n and S 3-Fig. 2g–i	[1] p. 20	S153622, S153623, S153626, S153627, S153632, S153634
Conifers (incl. Gnatales)			
Ephedraceae			
<i>Ephedra</i> sp./ <i>Ephedripites (Distachypites) tertianus</i>	Fig. 3p and S 3-Fig. 2m–o	[2] p. 10	S153622, S153627, S153634, S153636, S153637, S153639, S153640, S153646, S153648
Cupressaceae			
Cupressaceae gen. indet. 1	Fig. 5a and S 3-Fig. 3a–c	This study	ES
non-papillate/ <i>Cupressacites bockwitzensis</i>			
Cupressaceae gen. indet. 1	Fig. 5b and S 3-Fig. 3d–g	This study	ES
non-papillate/ <i>Inaperturopollenites dubius</i>			
Cupressaceae gen. indet. 2	Fig. 5c and S 3-Fig. 3h–k	This study	S153631, S153635–S153637, S153641, S153645
papillate/ <i>Inaperturopollenites concedipites</i>	Fig. 5d–g and S 3-Fig. 3l–s	This study	S153631, S153635
Cupressaceae gen. indet. 3			
papillate/ <i>Sequoiapollenites gracilis</i>			
Pinaceae			
<i>Cathaya</i> sp.	Fig. 5h–i and S 3-Fig. 4a–d	[1] p. 25	ES
<i>Cedrus</i> sp.	Fig. 5j and S 3-Fig. 4e–h	[1] p. 25	ES
<i>Picea</i> sp.	Fig. 5k and S 3-Fig. 4i–l	[1] p. 27	S153623, S153627, S153635–S153637, S153641, S153645
<i>Pinus</i> subgenus <i>Pinus</i> sp.	Fig. 5l and S 3-Fig. 4m–p	[1] p. 27	ES
<i>Pinus</i> subgenus <i>Strobilus</i> sp.	Fig. 5m and S 3-Fig. 4q–t	[1] p. 27	ES
<i>Tsuga</i> sp.	Fig. 4m–p	This study	S153623, S153648
Angiosperms			
Adoxaceae			
<i>Viburnum</i> sp.	Fig. 12j–m	This study	S153631
Amaranthaceae			
Amaranthaceae gen. indet. 1	Fig. 8s, t and S 3-Fig. 12g–i	This study	ES
Amaranthaceae gen. indet. 2	Fig. 8u and S 3-Fig. 12d–f	This study	ES
Amaranthaceae gen. indet. 3	Fig. 10g–i and S 3-Fig. 12j–l	This study	ES
Apiaceae			
Apiaceae type 1	Fig. 11n, o and S 3-Fig. 15k–n	This study	ES
Apiaceae type 2	Fig. 11p, q and S 3-Fig. 15o–r	This study	ES

Table 1 (continued)

Taxon	Figure (this paper)	Description (previous papers)	Occurrence
Apiaceae type 3	Fig. 11r, s and S 3-Fig. 16a–d	This study	ES
Apiaceae type 4	Fig. 11t, u and S 3-Fig. 16e–h	This study	ES
Apiaceae type 5	Fig. 11v, w and S 3-Fig. 16i–l	This study	ES
Apiaceae type 6	Fig. 11x, y and S 3-Fig. 16m–p	This study	ES
Saniculoidae gen. indet.	Fig. 11z–aa and S 3-Fig. 16q–t	This study	S153622, S153623, S153630, S153631, S153639
Aquifoliaceae			
<i>Ilex</i> sp.	Fig. 11c, d and S 3-Fig. 14a–c	[2] p. 25	S153637
Araliaceae			
Araliaceae gen. indet.	Fig. 13e–g	This study	S153641
Asteraceae			
Asteroidae type 1	Fig. 11g and S 3-Fig. 14d–f	[2] p. 25	– ^a
Asteroidae type 2	Fig. 11e and S 3-Fig. 14 g–i	This study	– ^a
Asteroidae type 3	Fig. 11f and S 3-Fig. 14j–l	This study	– ^a
Asteroidae type 4	Fig. 11j and S 3-Fig. 14m–o	[1] p. 58	– ^a
Asteroidae type 5	Fig. 11h, i and S 3-Fig. 15a–c	This study	– ^a
<i>Artemisia</i> sp.	Fig. 12g–i and S 3-Fig. 15d–f	This study	S153623
Cichorioideae gen. indet.	Fig. 14k–l and S 3-Fig. 15 g–j	This study	S153622, S153623, S153627, S153631, S153632, S153634, S153636, S153637, S153639
Betulaceae			
<i>Alnus</i> sp./ <i>Alnipollenites</i> <i>versus</i>	Fig. 7j and S 3-Fig. 6m–o	[1] p. 33	ES
<i>Betula</i> sp. 1	Fig. 7k, l and S 3-Fig. 7a–c	This study	ES
<i>Betula</i> sp. 2	Fig. 7m, n and S 3-Fig. 7d–f	This study	ES
<i>Carpinus</i> sp.	Fig. 7o and S 3-Fig. 7g–i	[1] p. 33	ES
<i>Corylus</i> sp.	Fig. 7p and S 3-Fig. 7j–l	[1] p. 34	ES, ^b
<i>Ostrya</i> sp.	Fig. 7q and S 3-Fig. 7m–o	[1] p. 34	ES, ^b
Buxaceae			
<i>Buxus</i> sp.	Fig. 7e, f and S 3-Fig. 6a–c	[1] p. 31	S153631, S153635–S153637, S153641, S153645
Cannabaceae			
<i>Celtis</i> vel <i>Pteroceltis</i> sp.	Fig. 8e, f and S 3-Fig. 10j–l	[2] p. 16	ES
Caprifoliaceae			
<i>Centranthus</i> sp.	Fig. 13a–d	This study	S153631
<i>Dipsacus</i> vel <i>Cephalaria</i> sp.	Fig. 11m	[2] p. 27	S153628, S153635, S153640.
<i>Valeriana</i> sp.	Fig. 12n–q	This study	S153636
Caryophyllaceae			
Caryophyllaceae gen. indet. 1	Fig. 8v, w and S 3-Fig. 12m–o	This study	S153622, S153623, S153626, S153634, S153635, S153637, S153639–S153641
Caryophyllaceae gen. indet. 2	Fig. 8x, y and S 3-Fig. 13a–c	This study	S153622, S153623, S153626, S153634, S153635, S153637, S153639–S153641
Droseraceae			
<i>Drosera</i> sp.	Fig. 10a–c	This study	S153636
Eucommiaceae			
<i>Eucommia</i> sp./ <i>Tricolpopollenites</i> <i>parvularius</i>	Fig. 11a, b and S 3-Fig. 13m–o	[1] p. 54	ES
Euphorbiaceae			
<i>Euphorbia</i> sp. 1	Fig. 6j–l	This study	S153622, S153623, S153627, S153635–S153637, S153639–S153641
<i>Euphorbia</i> sp. 2	Fig. 6m–o	This study	S153622, S153623, S153627, S153635–S153637, S153639–S153641
Fagaceae			
<i>Fagus</i> sp.	Fig. 7r–u and S 3-Fig. 8a–f	[1] p. 36	ES
<i>Quercus</i> sp. 1 (<i>Quercus</i> sect. <i>Cerris</i>)	Fig. 7v, w and S 3-Fig. 8g–i	[1] p. 36	ES
<i>Quercus</i> sp. 2 (<i>Quercus</i> sect. <i>Ilex</i>)	Fig. 7x, y and S 3-Fig. 8j–l	[1] p. 38	ES

Table 1 (continued)

Taxon	Figure (this paper)	Description (previous papers)	Occurrence
<i>Quercus</i> sp. 3 (<i>Quercus</i> sect. <i>Quercus</i>)	Fig. 7z-aa and S 3-Fig. 8m-o	[1] p. 38	ES, - ^c
Geraniaceae			
<i>Erodium</i> sp.	Fig. 8k and S 3-Fig. 11g-i	[1] p. 44	S153622, S153623, S153627
Juglandaceae			
Engelhardtioideae gen. indet. 1	Fig. 7cc-ff and S 3-Fig. 9d-i	[1] p. 38	ES
Engelhardtioideae gen. indet. 2	Fig. 7bb and S 3-Fig. 9a-c	This study	ES, - ^d
<i>Carya</i> sp./ <i>Caryapollenites simplex</i>	Fig. 7gg and S 3-Fig. 9j-l	[1] p. 40	ES
<i>Juglans</i> sp.	Fig. 7hh and S 3-Fig. 9m-o	[1] p. 40	ES except S153626, S153627, S153629, S153631, S153634, S153639
<i>Pterocarya</i> sp.	Fig. 8a, b and S 3-Fig. 10a-f	[1] p. 40	S153622, S153623, S153629, S153646
Lythraceae			
Lythraceae gen. indet. aff. <i>Ammannia</i>	Fig. 9j-l	This study	S153623, S153627, S153631, S153637, S153641, S153645, S153646
<i>Decodon</i> sp. 1			ES
<i>Decodon</i> sp. 2	Fig. 8l-n and S 3-Fig. 11j-l	[1] p. 44	ES
Malvaceae	Fig. 8o-q and S 3-Fig. 11m-o	This study	
<i>Tilia</i> sp./ <i>Intratritropollenites instructus</i>	Fig. 8r and S 3-Fig. 12a-c	[1] p. 46	S153623, S153631, S153632, S153639
Moraceae/Urticaceae			
Moraceae/Urticaceae gen. indet.	Fig. 9a-c	This study	S153623
Myricaceae			
<i>Morella</i> vel <i>Myrica</i> sp.	Fig. 8c, d and S 3-Fig. 10g-i	[1] p. 42	ES, - ^b
Oleaceae			
Oleaceae gen. indet. 1	Fig. 10m-o	This study	ES
Oleaceae gen. indet. 2	Fig. 12a-c	This study	ES
Oleaceae gen. indet. 3	Fig. 12d-f	This study	ES
Poaceae			
Poaceae gen. indet. 1	Fig. 5p-q and S 3-Fig. 5a-c	[1] p. 29	ES
Poaceae gen. indet. 2	Fig. 5n, o and S 3-Fig. 5d-f	This study	ES
Poaceae gen. indet. 3	Fig. 5r, s and S 3-Fig. 5g-i	This study	ES
Polygonaceae			
<i>Persicaria</i> sp./ <i>Persicartipollenites pliocenicus</i>	Fig. 10d-f	This study	S153632, S153634
<i>Rumex</i> sp.	Fig. 8z-aa and S 3-Fig. 13d-f	[1] p. 52	ES except S153622, S153626, S153627, S153637–S153640
Ranunculaceae			
Ranunculaceae gen. indet.	Fig. 6g-i	This study	S153623, S153636
Rosaceae			
<i>Rosaceae</i> gen. indet. 1	Fig. 9d-f	This study	ES
<i>Rosaceae</i> gen. indet. 2	Fig. 9m-o	This study	ES
Salicaceae			
<i>Salix</i> sp.	Fig. 7h, i and S 3-Fig. 6g-l	[2] p. 14	ES except S153622, S153626, S153627, S153632
Santalaceae			
<i>Arceuthobium</i> sp.	Fig. 6d-f	This study	S153634
Sapindales fam. et gen. indet.	Fig. 9m-o	This study	S153623
Sapindaceae			
<i>Acer</i> morphotype 1	Fig. 8bb-cc and S 3-Fig. 13g-i	[2] p. 18	ES
<i>Acer</i> morphotype 2	Fig. 8dd-ee and S 3-Fig. 13j-l	[2] p. 21	ES
Sapotaceae			
Sapotaceae gen. indet.	Fig. 10j-l	This study	S153631
Similaceae			
<i>Smilax</i> sp. <i>aspera</i> type	Fig. 6a-c	This study	S153637
Typhaceae			

Table 1 (continued)

Taxon	Figure (this paper)	Description (previous papers)	Occurrence
<i>Sparganium</i> sp.	Fig. 7a, b and S 3-Fig. 5j–l	[2] p. 12	ES
<i>Typha</i> sp.	Fig. 7c, d and S 3-Fig. 5m–o	[1] p. 29	ES
Ulmaceae			
<i>Cedrelospermum</i> sp.	Fig. 8g, h and S 3-Fig. 10m–o	[1] p. 42	ES
<i>Ulmus</i> sp.	Fig. 8i and S 3-Fig. 11a–c	[1] p. 44	ES
<i>Zelkova</i> sp.	Fig. 8j and S 3-Fig. 11d–f	[1] p. 44	ES
Incerta sedis			
Pollen type 1	Fig. 13h–j	This study	SI53623
Pollen type 2	Fig. 13k–m	This study	SI53632
Pollen type 3	Fig. 13n–p	This study	SI53637

Publication: [1] Bouchal et al. (2016), [2] Bouchal et al. (2017)

^a For occurrence, see Asteroideae in systematic palynology

^b For additional information, see *Corylus*

^c *Quercus* sp. 3 was observed less frequent than *Quercus* sp. 1 and 2

^d Engelhardtioideae gen. indet. 2 was observed less frequent than Engelhardtioideae gen. indet. 1

ES—present through the entire section

field is up to 18 m thick and split by several faults, leading to highly varying thickness of overburden (5–15 m at Salihpaşalar lignite mine, up to 493 m in other parts of the lignite field, see table 3 in Inaner et al. 2008). Three further opencast lignite mines are currently active in the YB, (i) the Eskihişar lignite mine located west of the Aladağ Mountain exploiting the Eskihişar and Turgut lignite fields; (ii) the Tınaz lignite mine, located in the southern part of the Tınaz subbasin; and (iii) the Bağyaka lignite mine, located in the northern part of the Tınaz subbasin (Fig. 1b). In recent years, the plant macrofossils and palynological assemblages of the Eskihişar and Tınaz lignite mines have been the focus of a rather high number of studies (Akgün et al. 2007; Benda 1971; Bouchal et al. 2016, 2017; Erdei et al. 2002; Gemici et al. 1990; Güner et al. 2017; Koç, 2017; Yavuz-Işık et al. 2011).

Sampled stratigraphic section

A stratigraphic column comprising 25 m (hereafter Salihpaşalar section; Fig. 1c) was sampled at 1-m intervals (mainly siliciclastic and marly sedimentary rocks alternated by lignite seams). Twenty-seven samples were collected of which 16 were suitable for palynological analysis (detailed information on samples is provided in S 1). The base of the Salihpaşalar section starts below the excavated lignite seam (uppermost part of the Turgut Member) with weakly consolidated, blueish-grey to dark grey, micaceous clayey siltstones. They are followed by a section of thin lignite seams (2–20 cm) intercalated with silty claystones (1–10 cm); indeterminable plant debris is common in these layers. This section is succeeded by the main lignite layers, which have a combined thickness of three to four meters. Its lower part is intercalated with thin clayey siltstones (> 1 cm), which are replaced in the upper part by light-grey to blueish-grey marls and clayey limestones (> 1 cm). The succeeding section comprises 19 m of grey clayey limestones and blueish-grey marls (0.01–2 m) alternating with lignites (1–50 cm). Leaf and root fossils as well as gastropods and mollusc shell debris occur in this part of the section but are rare or restricted to single horizons. The following yellowish-grey to yellowish-red clayey limestones were not further investigated or sampled. In 2015, the mining activity ceased and the pit was flooded with groundwater; therefore, the profile is no longer accessible.

Sample processing and data

Sedimentary rock samples were processed following the protocol described in Grímsson et al. (2008) and the same pollen grains were investigated using LM and SEM (single grain method, Zetter 1989). LM photographs of dispersed fossil pollen were taken with an Olympus BX51

Table 2 Securely identified pollen, spore/cyst taxa and their corresponding vegetation units (VU) in the published pollen floras of the Sakköy member of the Yatağan Basin

Palynotaxon/highest botanical determination	Yatağan Basin localities	Vegetation unit (VU)	Life form	Ecology (habitat)
Algae				
<i>Signapollis pseudosetarius</i> (2)	E, T, S, YB ^a	1, 2	Plankton	Eutrophic to mesotrophic open waters ^d
Algal cyst indet.	E, T, S	1, 2	Plankton	uncertain
Botryococaceae				
<i>Botryococcus</i> cf. <i>B. braunii</i>	E, T, S	1	Plankton	Open water, fresh to brackish ^d
Zygnemataceae				
<i>Spirogira</i> spp. (6)	E, T, S	1, 2	Plankton	Shallow, stagnant, oxygen-rich waters, lake margins ^a
<i>Mougeotia</i> sp.	YB ^a	1, 2	Plankton	Shallow, stagnant, oxygen-rich waters, lake margins ^a
Moss, fern and fern allies				
(= <i>Polyporipollenites fragilis</i>)				
<i>Leavigatosporites haardtii</i>	E, T, S, YB ^a	uncertain	Fern	uncertain
Sphagnaceae				
<i>Sphagnum</i> sp.	E, T, YB ^a	2, 3, 7	Moss	Swamp, moist conifer forests, mountain forests
Lycopodiaceae				
<i>Lycopodium</i> sp.	S, YB ^a	2, 3, 6b, 7	Moss	Swampy or moist conifer forests, mountain forests and exposed grassy or rocky sites
<i>Lycopodiella</i> sp.	S	2, 3, 7	Moss	Bogs, lake margins, marshes, wetlands on hillsides
Selaginellaceae				
<i>Selaginella</i> sp.	S	2, 4, 7	Moss	Meadows, mires, open environments (shade intolerant)
Osmundaceae				
<i>Osmunda</i> sp.	E, T, S, YB ^a	2–7	Fern	Indifferent, moist environments, acidic
Pitulariaceae				
<i>Platilaria</i> sp.	S	1–3	Fern	Fern Shallow water (ponds or temporary pools), lake margins, swamp
Pteridaceae				
<i>Pteris</i> spp. (2)	E, T, YB ^a	4–7	Fern	Fern well-drained lowland and upland forests, valleys, rocky ground
Conifers (incl. Gnetales)				
Ephedraceae				
<i>Ephedra</i> spp. (3)	E, T, S, Ç ^a , YB ^a	0, 5, 7	Shrubgym	Open, light forest
Cupressaceae				
Cupressaceae gen. indet. non-papillate (2)	E, T, S, Ç ^a , YB ^a , YE ^a	5–7	Shrubgym	Well-drained lowland and upland forests
Cupressaceae gen. indet. papillate (2)	E, T, S, Ç ^a , YB ^a , YE ^a	3, 5–7	Treegym	Swamp forest, well-drained lowland and upland forests
Pinaceae				
<i>Cathaya</i> spp. (2)	E, T, S, Ç ^a , YB ^a	6b, 7	Treegym	Well-drained lowland and upland forests
<i>Cedrus</i> sp.	E, T, S, Ç ^a , YB ^a	7	Treegym	Well-drained lowland and upland forests
<i>Larix</i> vel <i>Pseudotsuga</i>	YB ^a	7	Treegym	Well-drained lowland and upland forests
(= <i>Inaperturopollenites magnus</i>)				
<i>Picea</i> sp.	E, S, Ç ^a	7	Treegym	Well-drained lowland and upland forests
<i>Pinus</i> subgenus <i>Strobus</i> sp.	E, T, S, Ç ^a , YB ^a , YE ^a	0, 3–7	Treegym	Indifferent
(Haploxyton pollen type)				
<i>Pinus</i> subgenus <i>Pinus</i> sp.	E, T, S, Ç ^a , YB ^a , YE ^a	0, 3–7	Treegym	Indifferent
(Diploxyton pollen type)				
<i>Tsuga</i> spp. (2)	T, S, Ç ^a	7	Treegym	Well-drained lowland and upland forests
Angiosperms				
Adoxaceae				
<i>Viburnum</i> sp.	S	0, 4–7	Shrub	Indifferent
Altingiaceae				
<i>Liquidambar</i> sp.	T, S, Ç ^a , YB ^a	4–6	Tree	Riparian, well-drained lowland and upland forests
Amaranthaceae				
Amaranthaceae spp. (4)	E, T, S, Ç ^a , YB ^a , YE ^a	0	Herb	Open, disturbed areas, dry meadows, salty soils

Table 2 (continued)

Palynotaxon/highest botanical determination	Yatağan Basin localities	Vegetation unit (VU)	Life form	Ecology (habitat)
Anacardiaceae				
Anacardiaceae spp.	Ç ^a , YB ^a	0, 4–6	Tree, shrub	Indifferent
Apiaceae				
Apiaceae spp. (14)	E, T, S, Ç ^a , YB ^a , YE ^a	0, 2–7	Herb	Indifferent
Tribus Saniculoideae gen. indet. (3)	E, T, S	0, 2–7	Herb	Indifferent
Aquifoliaceae				
<i>Ilex</i> sp.	T, S, YB ^a	4–7	Shrub	Well-drained lowland and upland forests
Araliaceae				
Araliaceae gen. indet.	S, Ç ^a	uncertain	uncertain	Indifferent
Asteraceae				
<i>Artemisia</i> sp.	S, Ç ^a	0, 2–7	Herb	Indifferent
Asteroidae spp. (9)	E, T, S, Ç ^a , YB ^a , YE ^a	0, 2–7	Herb	Indifferent
Cichorioideae spp. (4)	E, T, S, Ç ^a , YB ^a , YE ^a	0, 2–7	Herb	Indifferent
Betulaceae				
<i>Alnus</i> sp.	E, T, S, Ç ^a , YE ^a , YB ^a	3–6	Tree, shrub	Swamp, riparian forest, well-drained low and upland forests
<i>Betula</i> spp.	E, T, S, Ç ^a , YE ^a	3–7	Tree	Riparian, well-drained lowland and upland forests
<i>Carpinus</i> sp.	E, T, S, Ç ^a , YB ^a , YE ^a	5a	Tree	Well-drained lowland forest
<i>Corylus</i> sp.	E, T, S, YB ^a	5, 6	Tree, shrub	Well-drained lowland and upland forests
<i>Ostrya</i> sp.	E, T, S	0, 5	Tree	Well-drained lowland forest
Buxaceae				
<i>Buxus</i> sp. (<i>balearica</i> type)	E, S, Ç ^a , YE ^a	5, 6	Shrub	Well-drained lowland and upland forests
Campanulaceae				
<i>Campanula</i> sp.	T, YE ^a	0, 2–7	Herb	Indifferent
Cannabaceae				
<i>Celtis</i> vel <i>Pteroceltis</i> sp.	T, S, Ç ^{ac} YE ^a	0, 3–6	Tree, shrub	Riparian, swamp, well-drained lowland and upland, open and light forests
Caprifoliaceae				
<i>Lonicera</i> spp. (3)	E, T, Ç ^a , YB ^a	0, 4–7	Shrub, liana	Indifferent
Limnaceoideae gen. indet.	E, T	4–7	Shrub	Well-drained lowland and upland forests
<i>Dipsacus</i> vel <i>Cephalaria</i> sp.	T, S	0, 3, 4	Herb	Open disturbed areas, light and riparian forests,
<i>Scabiosa</i> sp.	T	0, 5–7	Herb	Montane and lowland meadows
<i>Succisa</i> sp.	E	2, 7	Herb	Montane and lowland wet meadows
<i>Valeriana</i> sp.	S, YE ^a	0, 2–7	Herb	Indifferent
<i>Centranthus</i> sp.	S	0, 5a	Herb, subshrub	Open, dry shrubland
Caryophyllaceae				
Caryophyllaceae spp. (5)	E, T, S, Ç ^a , YE ^a	0, 2–7	Herb	Indifferent
Convolvulaceae				
<i>Convolvulus</i> sp.	E, T	0, 3–7	Herb	Indifferent
Droseraceae				
<i>Drosera</i> sp.	S	2–4, 7	Herb	Wet meadows, bogs, forest understories
Ericaceae				
Ericaceae spp. (tetrads)	E, Ç ^a	uncertain	uncertain	Indifferent
<i>Erica</i> sp.	E	5–7	Shrub	Indifferent
Eucommiaceae				
<i>Eucommia</i> sp.	E, T, S, Ç ^a	5, 6	Tree	Well-drained lowland and upland forests
Euphorbiaceae				
Euphorbiaceae spp.	E, T, Ç ^a	uncertain	uncertain	Indifferent
<i>Euphorbia</i> spp. (3)	E, T, S, Ç ^a	uncertain	uncertain	Indifferent
Fabaceae				
<i>Apios</i> sp. (= <i>Porcolopollenites rotundus</i>)	E	4–6	Liana	Riparian, well-drained lowland and upland forests
<i>Tricolporopollenites wackersdorffensis</i> ^b	E, T	4–5–	uncertain	Riparian and well-drained lowland forest ^e
Fagaceae				
<i>Fagus</i> sp.	E, T, S, Ç ^a	5b, 6b	Tree	Well-drained lowland and upland forests
<i>Quercus</i> subgen. <i>Cerris</i> sect. <i>Cerris</i> sp.	E, T, S, Ç ^{ac} YE ^{a, c}	5, 6	Tree	Well-drained lowland and upland forests

Table 2 (continued)

Palynotaxon/highest botanical determination	Yatağan Basin localities	Vegetation unit (VU)	Life form	Ecology (habitat)
<i>Quercus</i> subgen. <i>Cerris</i> sect. <i>Ilex</i> sp.	E, T, S, Ç ^a	5–7	Tree	Well-drained lowland and upland forests
<i>Quercus</i> subgen. <i>Quercus</i> sect. <i>Quercus</i> sp.	E, T, S, Ç ^a , YE ^a , c	3–7	Tree	Indifferent
Trigonoidae gen. indet.	E, T, Ç ^a , YB ^a , YE ^a	5–7	Tree	Well-drained lowland and upland forests
<i>Trigonobalanopsis</i> sp. ^b	E, T	uncertain	Tree	Not known
Geraniaceae				
<i>Erodium</i> sp.	E, T, S, Ç ^a	0, 2, 3	Herb	Open disturbed areas, riparian, floodplains
Juglandaceae				
Engelhardtioideae gen. indet. spp. (3) ^b	E, T, S, Ç ^a , YB ^a	5a	Tree	Well-drained lowland forest
<i>Carya</i> sp.	E, T, S, Ç ^a , YE ^a , YB ^a	3–5	Tree	Riparian, well-drained lowland and upland forests
<i>Juglans</i> sp.	E, S, Ç ^a , YB ^a , YE ^a	3–5	Tree	Riparian and well-drained lowland forests
<i>Pterocarya</i> vel <i>Cyclocarya</i> sp.	E, S, Ç ^a , YB ^a , YE ^a	4	Tree	Riparian forest
Lamiaceae				
Ajugoidae (<i>Clerodendrum</i> type)	T	0, 2–6	Herb, shrub	Indifferent
Linaceae				
<i>Linum</i> sp. (<i>austriacum</i> type)	E, T	0	Herb	Open, well-drained meadows, rocky areas
Lythraceae				
Lythraceae gen. indet. aff. <i>Ammannia</i> ^b	S	1–3	Herb ^c	Aquatic, riparian, lake margin
<i>Decodon</i> spp. (2)	E, T, S	2–4	Herb, shrub	Lake margin, swamp, riparian forest
Malvaceae				
	E, T, S, YE ^a	5b	Tree	Well-drained lowland forest
Moraceae vel Urticaceae				
Moraceae vel Urticaceae gen. indet.	S	0, 2–7	uncertain	Indifferent
Myricaceae				
<i>Morella</i> vel <i>Myrica</i> sp.	E, T, S, Ç ^a , YB ^a , YE ^a	2–5	Tree, shrub	Riparian, swamp and well-drained lowland forests
Nitriaceae				
<i>Nitaria</i> sp.				
Nyssaceae				
<i>Nyssa</i> sp.	YB ^a	0, 4	Shrub	Open areas, salty soils, lake margins
		3–5	Tree	Open areas, swamps, riparian, well-drained lowland forest
Oleaceae				
Oleaceae spp.	Ç ^a , YB ^a	0, 2–7	Tree, shrub	Indifferent
Oleaceae aff. <i>Olea</i> and <i>Chionanthus</i>	E, T, S	0, 4, 5a	Tree, shrub	Indifferent
Oleaceae <i>Phillyrea</i> , <i>Linociera</i> and <i>Noronhia</i>	E, T, S	0, 5	Tree, shrub	Indifferent
Oleaceae <i>Olea</i> , <i>Fontanesia</i> and <i>Osmanthus</i>	E, T, S	0, 4–6a	Tree, shrub	Indifferent
Oleaceae aff. <i>Olea</i> and <i>Osmanthus</i>	T	0, 4–6	Tree, shrub	Indifferent
Oleaceae aff. <i>Fraxinus</i>	E, T	4–6	Tree, shrub	Riparian and well-drained lowland and upland forests
Oleaceae aff. <i>Ligustrum</i>	T	0, 4–6a	Shrub, small tree	Indifferent
Onagraceae				
Onagraceae gen. indet.	Ç, YB ^a	0, 2–7	Herb, shrub, small tree	Indifferent
<i>Ludwigia</i> sp.	E	2–4		Riparian, lake margins, moist places
Poaceae				
Poaceae spp. (5)	E, T, S, Ç ^a , YB ^a	0, 2–7	Herb	Indifferent
Polygonaceae				
<i>Persicaria</i> sp. (<i>P. amphibia</i> type)	S	2–4	Herb	Lake margin, swamp, riparian forest, dry and wet meadows
<i>Polygonum</i> (<i>P. aviculare</i> type)				
<i>Rumex</i> sp.	E, T	0, 2–7	Herb	Indifferent
Ranunculaceae				
Ranunculaceae spp. (2)	T, S	0, 2–7	Herb	Indifferent
Rosaceae				
Rosaceae gen. indet. spp. (3)	E, S, Ç ^a , YE ^a	0, 3–7	Herb	Indifferent
Salicaceae				
<i>Salix</i> sp.	T, S, Ç ^a , YB ^a	2–4	Tree, shrub	Riparian forest
Santalaceae				
<i>Arceuthobium</i> sp.	S	4–7	Parasite	Parasite on gymnosperm trees

Table 2 (continued)

Palynotaxon/highest botanical determination	Yatağan Basin localities	Vegetation unit (VU)	Life form	Ecology (habitat)
Sapindales fam. indet.		0, 2–7	uncertain	Indifferent
Sapindaceae	E, T, S, Ç ^a , YB ^a	0, 2–7	Tree	Indifferent
<i>Acer</i> spp. (3)				
Sapotaceae	T, S, Ç ^a , YB ^a	4, 5	Tree	Riparian or well-drained lowland forest
Sapotaceae spp. (2)	YB ^a	4–6	Tree	Riparian, well-drained lowland and upland forests
Simaroubaceae	E			
aff. <i>Atlantus</i>				
<i>Picrostima</i> sp.	T	5, 6	Tree, shrub	Well-drained lowland and upland forests
Smilacaceae	S	3–5	Liana	Riparian and well-drained lowland forest
<i>Smilax</i> sp. (<i>aspera</i> type)				
Typhaceae	Ç ^a , YB ^a	2, 3	Herb	Bogs, wet meadows, lake margin
Typhaceae spp.	T, S	2, 3	Herb	Bogs, wet meadows, lake margin
<i>Sparganium</i> sp.	E, T, S	2, 3	Herb	Bogs, wet meadows, lake margin
<i>Typha</i> sp.				
Ulmaceae	E, T, S	4–5	Tree	Riparian and well-drained lowland forest ^f
<i>Cedrelospermum</i> sp. ^b	E, T, S, Ç ^a , YE ^a	0, 4–6	Tree	Riparian, well-drained lowland and upland forests
<i>Ulmus</i> sp.				
<i>Zelkova</i> sp.	E, T, S, Ç ^a , YE ^a	0, 4–6	Tree	Riparian, well-drained lowland and upland forests

Vegetation units follow Denk (2016)

Localities: E Eskişehir (Gemici et al. 1990; Bouchal et al. 2016); T Tınaz (Bouchal et al. 2017); S Salihpaşalar (this study); Ç Çatakağyaka (Jiménez-Moreno 2005; Yavuz-Işık et al. 2011); YE Yeni Eskişehir (Yavuz-Işık et al. 2011); YB Yatağan Basin (Akgün et al. 2007). Life form: *tree/shrubgym*, gymnospermous tree (+*Ephedra*); *Tree*, angiospermous tree; *Herb*, herbaceous angiosperm. Vegetation unit: (VU) 0, steppe-like meadows with shrubs and/or small trees scattered or in groups; VU 1, aquatic; VU 2, bogs, wet meadows; VU 3, swamp forest; VU 4, riparian forest; VU 5, well-drained lowland forest (a “hot” Engelhardioidae, Sapotaceae; b “temperate” Carpinus, Tilia) including levee forests; VU 6, well-drained upland forest (a seasonal dry; b fully humid); VU 7, well-drained (lowland and) upland conifer forest including hammocks and raised bogs within peat-forming vegetation

^a Not figured

^b Extinct

^c Uncertain presence

^d Worobiec (2014), literature inferring ecology for extinct taxa

^e Wang et al. (2007), literature inferring ecology for extinct taxa

^f Manchester (1989), literature inferring ecology for extinct taxa

microscope equipped with an Olympus DP71 camera. Specimens were sputter coated with gold and photographed using a Hitachi S-4300 cold field emission scanning electron microscope. For the pollen diagram, 400 palynomorphs were counted per sample. The terminology for pollen morphology follows mostly Punt et al. (2007) and Hesse et al. (2009). The pollen diagram (Fig. 2) was generated in C2 vers. 1.7.6, maps and sections were drawn in Adobe Illustrator 15.0.0 and photographs were cropped in Adobe Photoshop 12.0. Sediment samples, processed samples and SEM stubs are stored at the Swedish Museum of Natural History, Stockholm, under accession numbers S153622 to S153648.

Systematic palynology

Table 1 lists all taxa identified for and their occurrences through the Salihpaşalar section. A number of taxa have previously been described, discussed and figured from adjacent localities and coeval strata of the upper Turgut and lower Sekköy members (Bouchal et al. 2016, 2017). These taxa, although from different lignite mines of the YB, are not described here. Light microscopy and SEM documentation of all palynotaxa is provided in S 3.

Algae

Class Trebouxiophyceae Friedl, 1995

Family Botryococcaceae

Fig. 2 LM pollen count diagram of the Salihpaşalar mine section showing percentages of taxa. Abundance in percent. + = rare (<2.5%); x = *Botryococcus* colonies present, xx = *B.* colonies frequently encountered. Asterisk: taxon comprises several genera or infrageneric groups discernible in SEM but not in LM. Hence, these genera are not

considered in the pollen diagram. Abbreviations: S = small; L = large; SM = *Smilax*; AR = *Arceuthobium*; VA = *Valeriana*; CE = *Centranthus*. N = 400 pollen per sample. Sample numbers are indicated next to the simplified stratigraphic section

Genus *Botryococcus* Kützting, 1849

Botryococcus cf. *B. braunii* Kützting, 1849
(Fig. 3a and S 3-Figs. 1a–c)

Remarks: For remarks, see Bouchal et al. (2016, p. 17).

Class Zygnematophyceae Round, 1971

Family Zygnemataceae Kützting, 1843

Genus *Spirogyra* Link, 1820/*Ovoidites* R.Potonié, 1951
emend. Krutzsch, 1959

Spirogyra sp. 1/*Ovoidites lanceolatus* Takahashi et Jux, 1991
(Fig. 3b and S 3-Fig. 1d–f)

Remarks: For descriptions and remarks, see Bouchal et al. (2016, p. 20).

Spirogyra sp. 2/*Ovoidites microfoveolatus* Krutzsch et Pacltová, 1990
(Fig. 3c, d and S 3-Fig. 1g–i).

Remarks: For descriptions and remarks, see Bouchal et al. (2017, p. 4).

Spirogyra sp. 3/*Ovoidites spriggii* (Cookson et Dettmann, 1959) Zippi, 1998
(Fig. 3e and S 3-Fig. 1j–l)

Description: Zygospor or aplanospore, outline circular to broadly ovoidal, length of axis perpendicular to fissure 65–85 µm (LM, SEM), length of axis parallel to fissure 60–80 µm (LM, SEM); mesospore 1–1.5 µm thick (SEM); psilate (LM, SEM), if ruptured gap spanning from pole to pole.

Genus *Cycloovoidites* Krutzsch et Pacltová, 1990

Spirogyra sp. 4/*Cycloovoidites cyclus* (Krutzsch, 1959)
Krutzsch et Pacltová, 1990
(Fig. 3f–i and S3-Fig. 1m–o)

Description: Zygospor or aplanospore, outline nearly circular to broadly ovoidal, length of axis perpendicular to fissure 85–95 µm (LM, SEM), length of axis parallel to fissure 95–115 µm (LM, SEM); mesospore 2–2.5 µm thick (SEM); verrucate to rugulate (LM, SEM), verrucae diameter 1–2 µm, rugulae length 2–5 µm, rugulae width 1 µm (SEM), predetermined breaking fissure indicated by slightly raised ca 0.5–1 µm broad band spanning from pole to pole.

Remarks: This zygospor/aplanospore falls in the morphological range (shape, size, verrucate sculpture) of the fossil

species *Cycloovoidites cyclus* (Krutzsch and Pacltová 1990; Worobiec 2014). Zygnemataceae zygospor/aplanospor were combined in the pollen diagram. The fossil species of *Ovoidites* and *Cycloovoidites* are commonly associated with shallow, stagnant, oxygen-rich fresh waters and lake margins (see table 1 in Worobiec 2014).

Incerta sedis

Algal cyst indet. 1

(Fig. 3j–k and S 3 Fig. 2a–c)

Description: Cyst, spheroidal, outline circular, diameter 25–30 µm (LM, SEM); cyst wall 2–2.5 µm thick (LM); psilate (LM, SEM)

Remarks: Algal cysts of uncertain affinity were combined in the pollen diagram. Algal cysts indet. 1 differs by psilate surface from algal cysts previously reported from the YB (Bouchal et al. 2016, 2017).

Genus *Sigmopollis* Hedlung, 1965

Algal cyst indet. 2/*Sigmopollis pseudosetarius* (Weyland et Pflug, 1957) Krutzsch et Pacltová, 1990
(Fig. 3l–m and S 3-Fig. 2d–f).

Description: Cyst, spheroidal, outline circular, diameter 20–30 µm (LM, SEM); cyst wall 2.5–3 µm thick (LM, SEM); echinate (LM), echinus base width 0.5–0.8 µm, echinus length 2–4 µm (SEM).

Remarks: This fossil species is commonly associated with eutrophic to mesotrophic open freshwater (e.g. Worobiec 2014). *S. pseudosetarius* specimens previously reported from the YB by Bouchal et al. (2016, fig. 3L) differ by larger and nanoverrucate echini.

Division Tracheophyta Sinnott, 1935

Class Equisetopsida C.Agardh, 1825

Subclass Lycopodiidae Beketov, 1863

Family Lycopodiaceae Mirbel in Lamarck et Mirbel, 1802

Genus *Lycopodium* L., 1753/*Retitriletes* (Pierce, 1961)
Döring, Krutzsch, Mai et Schulz in Krutzsch 1963

Lycopodium sp./*Retitriletes annotinioides* Krutzsch, 1963
(Fig. 4a–c)

Description: Spore, oblate, amb convex triangular, equatorial diameter 30–45 µm (LM, SEM); exospore 1.5–2.5 µm thick without sculpture elements, 4–4.5 µm thick including sculpture elements (LM); trilete, laesurae 2/3 to 3/4 of spore radius; reticulate (LM, SEM), sculptural elements more prominent on distal face.

Fig. 3 LM overview (a–c, e, f, h, j, l, n–p) and SEM detail (d, g, i, k, m) micrographs of Botryococcaceae, Zygnemataceae, algal cysts, Osmundaceae, Ephedraceae and spores of uncertain affinities. **a** *Botryococcus* cf. *B. braunii* (S153627). **b** *Spirogyra* sp. 1/*Ovoidites lanceolatus* (S153623). **c, d** *Spirogyra* sp. 2/*Ovoidites microfoveolatus* (S153635), (**d**) surface detail. **e** *Spirogyra* sp. 3/*Ovoidites spriggii* (S153623). **f–i** *Spirogyra* sp. 4/*Cycloovoidites cyclus* (S153623), (**g, i**) surface detail. **j** Algal cyst type 1 (S153622). **k** Surface detail. **l, m** Algal cyst indet. 2/*Sigmopollis pseudosetarius* (S153623). **m** Surface detail. **n** *Osmunda* sp./*Baculatisporites nanus*, PV. **o** Monolete spore fam. et gen. indet./*Laevigatosporites haardtii* (S153622), EV. **p** *Ephedra* sp./*Ephedripites (Distachyapites) tertarius* (S153637), EV. Abbreviations: polar view (PV), equatorial view (EV). Scale bars 10 µm (a–c, e, f, h, j, l, n–p), 1 µm (d, g, i, k, m)

Remarks: The figured specimen corresponds in size and exospore ornamentation (reticulate) to extant *Lycopodium* (Tyron and Lugardon 1991), showing closest similarities to the *Lycopodium clavatum* type of Wilce (1972) and the *Lycopodium annotinum* type of Jones and Blackmore (1988). Spores of *Lycopodium* have previously been reported from middle Miocene localities of western Turkey: *Retitriteles* (Akgün et al. 2007, Appendix A), *Lycopodium* (Akkiraz 2011, fig. 7J; Akkiraz et al. 2012).

Genus *Lycopodiella* Holub, 1964/*Camazonosporites* Pant, 1954 ex R.Potonié, 1956

Lycopodiella sp./*Camazonosporites helenensis* Krutzsch 1963 (Fig. 4d–f).

Description: Spore, oblate, amb convex triangular, equatorial diameter 30–40 µm (LM, SEM); exospore 2.3–2.8 µm thick including sculpture elements (LM); trilete, laesurae 2/3 to 3/4 of spore radius; rugulate on distal face (LM, SEM).

Remarks: Spores of this type correspond in size and exospore ornamentation to extant *Lycopodiella* (Tyron and Lugardon 1991), with closest morphological similarities to the *Lycopodiella cernuum* type of Wilce (1972) and the *Lycopodiella inundata* type of Jones and Blackmore (1988). The term hamulate has been used to describe the rugulate sculpture of *Lycopodiella* spores (Krutzsch 1963; Jones and Blackmore 1988).

Family Selaginellaceae Willk. in Willk. et Lange, 1861
Genus *Selaginella* P.Beauv., 1804/*Echinatisporites* Krutzsch 1959

Selaginella sp./*Echinatisporites miocenicus* Krutzsch et Sontag in Krutzsch 1963 (Fig. 4g–i)

Description: Spore, oblate, amb convex triangular, length of polar axis 35–45 µm (LM, SEM), equatorial diameter 45–

55 µm (LM, SEM); exospore 2.5–3 µm thick without sculpture elements (LM); trilete, laesurae 2/3 to 3/4 of spore radius; echinate (LM, SEM), echini absent on proximal face, echini length 3–5.5 µm (LM, SEM).

Remarks: Echinate spores of this type correspond in size and exospore ornamentation to extant *Selaginella selaginoides* (L.) Link (Stafford 1991; Tyron and Lugardon 1991).

Spores of *Selaginella* have previously been reported from middle Miocene localities of western Turkey: *Echinatisporites* (Akgün et al. 2007, Appendix A), *Selaginella* (Akkiraz et al. 2012, pl. 1, fig. 5).

Monilophytes

Subclass Polypodiidae Cronquist, Takht. et Zimmerm., 1966

Family Marsileaceae Mirbel, 1802

Genus *Pilularia* L., 1753

Pilularia sp.

(Fig. 4j–l)

Description: Microspore, oblate, amb circular, length of polar axis 30–35 µm (LM, SEM), equatorial diameter 35–45 µm (LM, SEM); exospore 3.5–4.5 µm thick (LM), compact, episore (uncondensed) three times thicker than exospore (LM); trilete, laesurae ¼ to ½ of spore radius; scabrate (LM), rugulate, fossulate (SEM) dented or folded in central area.

Remarks: The morphology (sporewall architecture, episore sculpturing) of the available specimen corresponds to microspores of extant *Pilularia* (Tyron and Lugardon 1991), with closest similarities to the *Pilularia globulifera* type of Stafford (1995). Nakoman (1967), *Anatoliensisporites ornatiturcicus* Nakoman, pl. 1, fig. 14 and Akgün and Akyol (1999, indetermined form, fig. 10.41) reported morphologically similar spores from Miocene strata of Anatolian.

Family Osmundaceae Bercht. et Presl, 1820

Genus *Osmunda* L., 1753/*Baculatisporites* P.W.Thomson et Pflug, 1953

Osmunda sp./*Baculatisporites nanus* (Wolff, 1934) Krutzsch, 1959

(Fig. 3n and S 3-Fig. 2g–i)

Remarks: For descriptions and remarks, see Bouchal et al. (2016, p. 20).

Incerta sedis

Genus *Laevigatosporites* Ibrahim, 1933

Fig. 4 LM overview (a, d, g, j, m), SEM overview (b, e, h, k, n) and SEM detail (c, f, i, l, o, p) micrographs of Lycopodiaceae and Marsileaceae spores and Pinaceae pollen. a–c *Lycopodium* sp. (S153622), (a) PV, (b, c) DV. d–f *Lycopodiella* sp. (S153627), (d) PV, (e, f) DV. g–i *Selaginella* sp. (S153648), (g) EV, (h, i) DV. j–l *Pilularia* sp. (S153623), (j) EV, (k, l) DV. m–p *Tsuga* sp. (S153648), (m) EV, (n) DV, (o) saccus detail, (p) leptoma detail. Abbreviations: PV, polar view; EV, equatorial view; DV, distal view. Scale bars, 10 µm (a, b, d, e, g, h, j, k, m, n), 1 µm (c, f, i, l, o, p)

Monolete spore fam. indet./*Laevigatosporites haardti* (R.Potonié et Venitz, 1934) P.W.Thomson et Pflug, 1953 (Fig. 3o and S 3-Fig. 2j–l).

Remarks: Several extant fern families (e.g. Aspleniaceae, Davalliaceae, Dryopteridaceae, Gleicheniaceae, Lomariopsidaceae, Oleandraceae, Thelypteridaceae, Vittariaceae, Polypodiaceae; see Tyron and Lugardon 1991) produce psilate, monolete spores similar to the fossil species *Laevigatosporites haardti*. For descriptions and further remarks, see Bouchal et al. (2016, p. 23; 2017, p. 6).

Subdivision Spermatophyta Willkomm, 1854

Gymnosperms

Subclass Gnetidae Pax in Prantl, 1894

Order Ephedrales Dumort., 1829

Family Ephedraceae Dumort., 1829

Genus *Ephedra* L., 1753/*Ephedripites* (*Distachypites*) Bolchovitina, 1953 emend. Krutzsch 1970

Ephedra sp./*Ephedripites* (*Distachypites*) *tertiarius* Krutzsch, 1970

(Fig. 3p and S 3-Fig. 2m–o).

Remarks: For descriptions and remarks, see Bouchal et al. (2017, p. 10).

Subclass Pinidae Cronquist, Takht. et Zimmerm., 1966

Order Pinales Gorozh., 1904

Family Cupressaceae Rich. ex Bartling, 1830

Cupressaceae gen. indet. 1 “non-papillate”

(Fig. 5a, b and S 3-Fig. 3a–g)

Description: Pollen, shape spheroidal, outline circular with a deep split to spindle-like (folded), diameter 25–40 µm (LM), 20–38 µm (SEM); exine 1–1.5 µm thick (LM); leptoma without papilla (LM, SEM); scabrate (LM), microverrucate (SEM), microverrucae covered with blunt nanoechini, leptoma area less ornamented, orbicules covered with blunt nanoechini, orbicule diameter 0.3–0.6 µm (SEM).

Remarks: Non-papillate pollen is commonly produced by Cupressaceae. No further allocation is possible owing to poor preservation and general lack of diagnostic morphological

characters of the available specimens (compare Van Campo-Duplan 1951, 1953; Kedves 1985). Spindle-shaped non-papillate, ruptured pollen (Fig. 5a and S 3-Fig. 3a–c) can be assigned to the fossil species *Cupressacites bockwitzensis* Krutzsch, while non-papillate, ruptured pollen with circular outline (Fig. 5b and S 3-Fig. 3d–f) fit the morphological range of the fossil species *Inaperturopollenites dubius* (R.Potonié et Venitz) P.W.Thomson et Pflug, (e.g. Stuchlik et al. 2002).

Genus *Inaperturopollenites* Pflug et P.W.Thomson in P.W.Thomson et Pflug, 1953

Cupressaceae gen. indet. 2 “papillate”/*Inaperturopollenites concedipites* (Wodehouse, 1933) Krutzsch, 1971 (Fig. 5c and S 3-Fig. 3h–k)

Description: Pollen, shape spheroidal, outline circular with deep split, diameter 25–40 µm (LM, SEM); exine 1–1.5 µm thick in leptoma area (LM); leptoma papillate (LM, SEM); scabrate (LM), microverrucate (SEM), microverrucae covered with blunt nanoechini, leptoma less ornamented (nano-verrucate), specimens can sporadically have a wrinkly leptoma, orbicules covered with blunt microechini, orbicule diameter 0.3–0.7 µm (SEM).

Remarks: Ruptured and unruptured papillate Cupressaceae pollen were combined in the pollen diagram. In extant Cupressaceae, papillate pollen is produced in a few subfamilies, namely Athrotaxioideae (*Athrotaxis* D.Don), Sequoiioideae (*Metasequoia* Hu et W.C.Cheng, *Sequoia* Endl., *Sequoiadendron* J.Buchholz), Taiwanioideae (*Taiwania* Hayata) and Taxodioideae (*Cryptomeria* D.Don, *Glyptostrobus* Endl., *Taxodium* Rich., see Van Campo-Duplan 1951; Kvavadze 1988). Pollen of this type commonly ruptures from proximal to the papillate distal pole during the hydration process preceding pollen germination (Southworth 1988) leading to its characteristic shape (Fig. 5c). Owing to this deformed state, no further generic determination is recommended.

Genus *Sequoiapollenites* Thiergart, 1938 ex R.Potonié, 1958

Cupressaceae gen. indet. 3 “papillate”/*Sequoiapollenites gracilis* Krutzsch, 1971 (Fig. 5d–g and S 3-Fig. 3l–s)

Description: Pollen, shape spheroidal, outline circular, polar axis 23–29 µm (LM), 22–25 µm (SEM), equatorial diameter 26–33 µm (LM), 22–27 µm (SEM), leptoma diameter 15–21 µm (LM), papilla length 2.5–3.5 µm; exine 1–1.5 µm thick (LM); leptoma papillate (LM, SEM), papilla straight to bent; scabrate (LM), microverrucate (SEM), microverrucae covered with blunt nanoechini, leptoma less ornamented (nanoverrucate), orbicules covered with microechini, orbicule diameter 0.2–0.7 µm (SEM).

◀ **Fig. 5** LM overview (a–d, f, h, j–n, p, r) and SEM detail (e, f, i, o, q, s) micrographs of Cupressaceae, Pinaceae and Poaceae pollen. **a** Cupressaceae gen. indet. 1 “non-papillate”/*Cupressacites bockwitzensis* (S153627). **b** Cupressaceae gen. indet. 1 “non-papillate”/*Inaperturopollenites dubius* (S153629), PV. **c** Cupressaceae gen. indet. 2 “papillate”/*Inaperturopollenites concedipites* (S153631), PV. **d–g** Cupressaceae gen. indet. 3 “papillate”/*Sequoiapollenites gracilis*. **d–e** (S153631), (**d**) EV, (**e**) detail PRV. **f–g** (S153635), (**f**) EV, (**g**) detail PRV. **h, i** *Cathaya* sp. (S153632), PV. (**i**) detail nanoechinata sculpture of corpus PRV. **j** *Cedrus* sp. (S153623), PV. **k** *Picea* sp. (S153641), PV. **l** *Pinus* subgenus *Pinus* sp. (S153627), PV. **m** *Pinus* subgenus *Strobus* sp. (S153631), EV. **n, o** Poaceae gen. indet. 2 (S153629), (**n**) PV, (**o**) exine sculpture detail. **p–q** Poaceae gen. indet. 1 (S153622), (**p**) EV, (**q**) exine sculpture detail. **r, s** Poaceae gen. indet. 3 (S153622), (**r**) PV, (**s**) exine sculpture detail. Abbreviations: PV, polar view; EV, equatorial view; PRV, proximal view (PRV). Scale bars, 10 µm (a–d, f, h, j–n, p, r), 1 µm (e, f, i, o, q, s)

Remarks: Unruptured papillate Cupressaceae pollen is much rarer than ruptured pollen due to its germination modus operandi (see above). The here depicted specimens fit within the morphological (size, papilla size) range of extant Taxodioideae and Sequoioideae (Kvavadze 1988). Macrofossil remains belonging to both subfamilies have been reported from Miocene localities in Turkey (Kasapligil 1977; Mädler and Steffens 1979; Paicheler and Blanc 1981; Gemici et al. 1991, 1993; Denk et al. 2017).

Family Pinaceae Spreng. ex F.Rudolphi, 1830

Genus *Cathaya* Chun et Kuang, 1958

Cathaya sp.

(Fig. 5h, i and S 3-Fig. 4a–d)

Remarks: For descriptions and remarks, see Bouchal et al. (2016, p. 25).

Genus *Cedrus* Trew, 1757

Cedrus sp.

(Fig. 5j and S 3-Fig. 4e–h).

Remarks: For descriptions and remarks, see Bouchal et al. (2016, p. 25).

Genus *Picea* A.Dietr., 1824

Picea sp.

(Fig. 5k and S 3-Fig. 4i–l)

Remarks: For descriptions and remarks, see Bouchal et al. (2016, p. 27).

Genus *Pinus* L., 1753

Subgenus *Pinus* L., 1753

Pinus subgenus *Pinus* sp.

(Fig. 5l and S 3-Fig. 4m–p)

Remarks: Near spherical sacchi with narrow attachment to the corpus are characteristic for *Pinus* subgenus *Pinus* (Diploxylon) pollen (e.g. Hesse et al. 2009). For descriptions and further remarks, see Bouchal et al. (2016, p. 27).

Genus *Pinus* L., 1753

Subgenus *Strobus* Lemmon, 1895

Pinus subgenus *Strobus* sp.

(Fig. 5m and S 3-Fig. 4q–t)

Remarks: Half-spherical sacchi with broad attachment to the corpus are characteristic of *Pinus* subgenus *Strobus* (Haploxylon) pollen type (e.g. Hesse et al. 2009). For descriptions and further remarks, see Bouchal et al. (2016, p. 27).

Genus *Tsuga* Carrière, 1847

Tsuga sp.

(Fig. 4m–p).

Description: Pollen, monosaccate, shape oblate, circular in polar view, equatorial diameter 55–70 µm (LM), 55–60 µm (SEM); rugulate (LM); leptoma verrucate to rugulate, echinate; monosaccus rugulate, fossulate, echinate, proximal face rugulate to verrucate, fossulate, echinate (SEM).

Remarks: Grímsson and Zetter (2011) recognised four distinct pollen morphologies in extant *Tsuga*: (1) bisaccate group, (2) monosaccate, nonechinata group, (3) monosaccate, echinate, narrow monosaccus group and (4) monosaccate, echinate, broad monosaccus group. The fossil *Tsuga* sp. can be assigned to the fourth group and has closest morphological similarities (density of echini, broad saccus) with pollen of extant *Tsuga diversifolia* (Maxim.) Mast. and *Tsuga forresti* Downie (Sivak 1978; Miyoshi et al. 2011). *Tsuga* pollen with narrow monosaccus and no echini has previously been reported from the Tnáz lignite mine (Bouchal et al. 2017, pl. 7.13–16).

Subclass Magnoliidae Novák ex Takht., 1967

Order Liliales Perleb, 1826

Family Smilacaceae Vent., 1799

Genus *Smilax* L., 1753

Smilax sp. “aspera type”

(Fig. 6a–c)

Description: Pollen, shape spheroidal, outline circular, diameter (including echini) 20–24 µm (LM), 19–22 µm (SEM); possibly atectate, exine ca 1 µm thick (LM), sexine thinner than nexine; inaperturate (LM, SEM); echinate (LM), echinate, nanoverrucate, perforate (SEM), echini base

◀ **Fig. 6** LM overview (a, d, g, j, m), SEM overview (b, e, h, k, n) and detail (c, f, i, l, o) micrographs of Smilacaceae, Ranunculaceae, Euphorbiaceae and pollen. a–c *Smilax* sp. (S153637), EV. d–f *Arceuthobium* sp. (S153634). g–i Ranunculaceae gen. indet. (S153623), EV. j–l *Euphorbia* sp. 1 (S153636), PV. m–o *Euphorbia* sp. 2 (S153627), EV. Abbreviations: PV, polar view; EV, equatorial view, proximal view. Scale bars, 10 µm (a, b, d, e, g, h, j, k, m, n), 1 µm (c, f, i, l, o)

diameter 0.5–1.5 µm (SEM), echini length 0.6–1.7 µm (SEM).

Remarks: Chen et al. (2006) identified four main pollen types within extant Smilacaceae; (1) *Smilax aspera* type (inaperturate, echinate), (2) *Heterosmilax* type (inaperturate, verrucate, nanoechinata), (3) *Smilax smallii* type (pseudocolporate, granulate) and (4) *Ripogonum* type (sulcate, microreticulate to reticulate). *Smilax* sp. corresponds by its spheroidal shape, echinate and nanoverrucate sculpture and lack of aperture to the *S. aspera* type pollen. Leaves of *Smilax miohavanensis* Denk, D.Velitzelos, T.Güner et Ferrufino-Acosta have previously been reported from the YB (Denk et al. 2015, Güner 2016, Güner et al. 2017). Small, spheroidal, echinate pollen has previously been reported from other middle Miocene localities of western Turkey: *Smilacipites* Wodehouse (Takahashi and Jux 1991, pl. 6, only fig. 2a, b), possibly *Echinigraminidites moravicus* Krutzsch (Akgün and Akyol 1999).

Order Poales Small, 1903

Family Poaceae Barnhart, 1895

Poaceae gen. indet. 1

(Fig. 5p, q and S 3-Fig. 5a–c)

Remarks: For descriptions and remarks, see Bouchal et al. (2016, p. 29).

Poaceae gen. indet. 2

(Fig. 5n, o and S 3-Fig. 5d–f)

Description: Pollen, shape spheroidal, equatorial outline circular, diameter 20–30 µm (LM, SEM); eutectate, exine 1–1.5 µm thick (LM); ulcerate, ulcus diameter 1.4–1.8 µm (SEM), annulus present; scabrate (LM), areolate, nanoechinata, fossulate, 3–9 nanoechini per areola, acute nanoechini (SEM).

Remarks: Poaceae gen. indet. 1, 2 and 3 were combined in the pollen diagram. Several extant Poaceae genera (e.g. *Avena* L., *Oryza* L., *Phragmites* Adanson, *Spartina* Schreber) produce areolate, nanoechinata pollen (Page 1978; Köhler and Elsbeth 1979). Poaceae gen. indet. 2 differs from Poaceae gen. indet. 1 by its smaller size and acute nanoechini.

Poaceae gen. indet. 3

(Fig. 5r, s and S 3-Fig. 5g–i)

Description: Pollen, shape spheroidal, equatorial outline circular, equatorial diameter 40–60 µm (LM, SEM); eutectate, exine 1–1.5 µm thick (LM); ulcerate, ulcus diameter 2–3 µm (SEM), weak annulus present (LM); scabrate (LM), nanoechinata, fossulate (SEM), blunt nanoechini (SEM).

Remarks: Poaceae gen. indet. 3 differs from Poaceae gen. indet. 1 and 2 by its markedly larger size and lack of areolae. A number of extant Poaceae genera produce pollen with nonclustered, blunt nanoechini, e.g. *Stipa* L., *Diandrolyra* Stapf, *Glyceria* Nutt. and *Secale* L. (Page 1978; Köhler and Elsbeth 1979). Poaceae gen. indet. 3 shares morphological characters (aperture, spaced nanoechini) with pollen previously reported from the Tınaz section, YB (Bouchal et al. 2017, Poaceae gen. indet. 3, p. 12, pl. 5.5–7) but differs by more densely spaced nanoechini.

Family Typhaceae Juss., 1789

Genus *Sparganium* L., 1753

Sparganium sp.

(Fig. 7a, b and S 3-Fig. 5j–l)

Remarks: For descriptions and remarks, see Bouchal et al. (2017, p. 12).

Genus *Typha* L., 1753

Typha sp.

(Fig. 7c, d and S 3-Fig. 5m–o)

Remarks: For descriptions and remarks, see Bouchal et al. (2016, p. 29).

Eudicots

Order Ranunculales Juss. ex Bercht. et J.Presl, 1820

Family Ranunculaceae Juss., 1789

Ranunculaceae gen. indet.

(Fig. 6g–i)

Description: Pollen, shape prolate, outline elliptic in equatorial view, length of polar axis 22–28 µm (LM, SEM), equatorial diameter 18–20 µm (LM), 16–18 µm (SEM); tectate, exine 1.5–2 µm thick (LM), nexine thinner than sexine; tricolpate, colpus length 2/3 to 3/4 of polar axis; scabrate (LM), microechinate, perforate (SEM), microechini base diameter 0.2–0.4 µm (SEM), microechini height 0.2–0.4 µm (SEM).

◀ **Fig. 7** LM overview (a, c, e, g–p, r, t, v, x, z, aa, cc, ee, ff). SEM overview (dd) and detail (b, d, f, q, s, u, w, y, bb) micrographs of Typhaceae, Buxaceae, Altingiaceae, Salicaceae, Betulaceae, Fagaceae and Juglandaceae pollen. a, b *Sparganium* sp. (S153623). c, d *Typha* sp. (S153623), DV. e, f *Buxus* sp. (S153631). g *Liquidambar* (S153622). h, i *Salix* sp., (h) EV (S153623), (i) EV (S153637). j *Alnus* sp./*Alnipollenites verus* (S153648), PV. k–l *Betula* sp. 1 (S153646), PV. m, n *Betula* sp. 2 (S153629), PV. o *Carpinus* sp. (S153626), PV. p *Corylus* sp. (S153631), PV. q *Ostrya* sp. (S153635), PV. r–u *Fagus* sp. (S153623), EV. v–w *Quercus* sp. 1 (*Quercus* sect. *Cerris*) (S153637), EV. x, y *Quercus* sp. 2 (*Quercus* sect. *Ilex*) (S153622), left EV, right PV. z–aa *Quercus* sp. 3 (*Quercus* sect. *Quercus*) (S153648), PV. bb Engelhardioideae gen. indet. 2 (S153622), PV. cc–ff Engelhardioideae gen. indet. 1, (S153622) PV, (S153627) PV, (ee, ff) pseudocolpus-like folds. gg *Carya* sp./*Caryapollenites simplex* (S153627), PV. hh *Juglans* sp. (S153629), PV. Abbreviations: PV, polar view; EV, equatorial view, proximal view. Scale bars, 10 µm (a, c, e, g–p, r, t, v, x, z, aa, cc–ff), 1 µm (b, d, f, q, s, u, w, y, bb)

Remarks: Ranunculaceae gen. indet. falls within the morphological range of the *Ranunculus acris* type of Clark et al. (1991). It is produced by several extant genera of this family (e.g. *Anemone* L., *Ceratocephalus* L., *Clematis* L., *Pulsatilla* Mill., *Ranunculus* L.).

Order Buxales Takht. ex Reveal, 1996
Family Buxaceae Dumort., 1822
Genus *Buxus* L., 1753

Buxus sp. balearica type
(Fig. 7e, f and S 3-Fig. 6a–c)

Remarks: For descriptions and remarks, see Bouchal et al. (2016, p. 31).

Order Saxifragales Bercht. et J.Presl, 1820
Family Altingiaceae (Horan., 1841) Lindl., 1846
Genus *Liquidambar* L., 1753

Liquidambar sp.
(Fig. 7g and S 3-Fig. 6d–f)

Remarks: For descriptions and remarks, see Bouchal et al. (2017, p. 12).

Fabids
Order Malpighiales Juss. ex J.Presl, 1820
Family Euphorbiaceae Juss., 1789
Genus *Euphorbia* L., 1753

Euphorbia sp. 1
(Fig. 6j–l)

Description: Pollen, outline circular to lobate in polar view, equatorial diameter 40–45 µm (LM), 35–40 µm (SEM); eutectate, exine 3–4 µm thick (LM), nexine thinner than sexine; tricolpate, colpus length 2/3 to 3/4 of polar axis, in

colpus area psilate margo present; perforate, microreticulate (LM, SEM).

Remarks: *Euphorbia* sp. 1 and 2 were combined in the pollen diagram. *Euphorbia* sp. 1 corresponds to subtype 1a.-*Euphorbia villosa* of El-Ghazaly and Chaudhary (1993); this type is produced by several species of *Euphorbia* which are not part of a natural group (El-Ghazaly and Chaudhary 1993). Highly similar *Euphorbia* pollen has been reported by Bouchal et al. (2016, as *Euphorbia* sp., p. 31, fig. 9G–J), corresponding in exine architecture and margo presence, but differing by prolate shape and perforate exine sculpture.

Euphorbia sp. 2 (Fig. 6m–o).

Description: Pollen, shape prolate, outline elliptic in equatorial view, polar axis 31–36 µm (LM), 30–34 µm (SEM), equatorial diameter 22–28 µm (LM), 21–25 µm (SEM); eutectate, exine 2–2.5 µm thick (LM), nexine thinner than sexine, thickened in aperture area; tricolporate, endoporus circular, colpus length 3/4 to 5/6 of polar axis; microreticulate (LM), microreticulate to fossulate-perforate (SEM).

Remarks: *Euphorbia* sp. 2 corresponds in size and sunken colpi to type 2-*Euphorbia nutans* of El-Ghazaly and Chaudhary (1993), which is produced by several not closely related *Euphorbia* species.

Family Salicaceae Mirb., 1815
Genus *Salix* L., 1753

Salix sp.
(Fig. 7h, i and S 3-Fig. 6g–l)

Remarks: For descriptions and remarks, see Bouchal et al. (2017, p. 14).

Order Fagales Engler, 1892
Family Betulaceae Gray, 1822
Genus *Alnus* Mill., 1754/*Alnipollenites* R.Potonié, 1931 emend. Grabowska et Ważyńska, 2009

Alnus sp./*Alnipollenites verus* (R.Potonié, 1931) R.Potonié, 1931 (Fig. 7j and S 3-Fig. 6m–o)

Remarks: For descriptions and remarks, see Bouchal et al. (2016, p. 33).

Genus *Betula* L., 1753

Betula sp. 1
(Fig. 7k, l and S 3-Fig. 7a–c)

Description: Pollen, shape oblate, outline circular in polar view, equatorial diameter 21–26 μm (LM, SEM); eutectate, exine 1–1.5 μm thick (LM), nexine thinner than sexine; triporate, pori circular, pori diameter 1–1.5 μm (LM, SEM), annulus formed by sexine, vestibulum present; scabrate (LM), microrugulate to microverrucate, nanoechinate, perforate (SEM), nanoechini positioned on microrugulae/microverrucae.

Betula sp. 2 (Fig. 7m, n and S 3-Fig. 7d–f)

Description: Pollen, shape oblate, outline convex triangular in polar view, equatorial diameter 25–32 μm (LM, SEM); eutectate, exine 1.5–2 μm thick (LM), nexine thinner than sexine; triporate, pori circular to elongated, pori diameter 1–2 μm (LM, SEM), annulus formed by sexine, vestibulum present; scabrate (LM), microrugulate, nanoechinate (SEM), nanoechini positioned on microrugulae.

Remarks: *Betula* sp. 1 and 2 were combined in the pollen diagram. *Betula* sp. 1 and 2 display a distinct vestibulum, the distinguishing character for pollen of this genus (e.g. Blackmore et al. 2003; Beug 2004; Stuchlik et al. 2009; Grímsson et al. 2016). *Betula* sp. 2 differs from *Betula* sp. 1 by larger size, thicker exine, mainly microrugulate sculpture and more spacious nanoechini. For further remarks concerning *Betula*, see Bouchal et al. (2016, p. 34).

Genus *Carpinus* L., 1753

Carpinus sp.

(Fig. 7o and S 3-Fig. 7g–i)

Remarks: For descriptions and remarks, see Bouchal et al. (2016, p. 33).

Genus *Corylus* L., 1753

Corylus sp.

(Fig. 7p and S 3-Fig. 7j–l)

Remarks: Dispersed and poorly preserved pollen of *Corylus*, *Ostrya* and *Morella* vel *Myrica* is difficult to unambiguously assign to one of these genera using only LM, owing to a high degree of morphological similarities (cf. Edwards 1981). Therefore, these three taxa were combined in the pollen diagram in the category *Corylus/Ostrya/Morella* vel *Myrica*. So far, only macrofossils of *Myrica* have previously been reported from the YB (Güner 2016; Güner et al. 2017). For descriptions and remarks, see Bouchal et al. (2016, p. 34).

Genus *Ostrya* Scop., 1760

Fig. 8 LM overview (a–c, e, g, i–l, o, r–w, y, aa), SEM overview (m, p, bb) and detail (d, f, h, n, q, t, y, aa) micrographs of Juglandaceae, Myricaceae, Cannabaceae, Ulmaceae, Geraniaceae, Lythraceae, Malvaceae, Amaranthaceae, Caryophyllaceae, Polygonaceae and Sapindaceae pollen. a, b *Cyclocarya* vel *Pterocarya* sp. (a) exceptionally large specimen, PV (S153646), (b) PV (S153629). c, d *Morella* vel *Myrica* sp. (S153637), PV. e, f *Celtis* vel *Pteroceltis* (S153632), PV. g, h *Cedrelospermum* sp. (S153635), PV. i *Ulmus* sp. (S153629), PV. j *Zelkova* sp. (S153646), PV. k *Erodium* sp. (S153622), PV. l–n *Decodon* sp. 1 (S153635), EV. m–q *Decodon* sp. 2 (S153627), EV. r *Tilia* sp./*Intratritropollenites instructus* (S153633), PV. s, t *Amaranthaceae* gen. indet. 1 (S153622). u *Amaranthaceae* gen. indet. 2 (S153623). v, w *Caryophyllaceae* gen. indet. 1 (S153622). x, y *Caryophyllaceae* gen. indet. 2 (S153622). z, aa *Rumex* sp. (S153623), EV. bb–cc *Acer* morphotype 1 (S153627), EV. dd–ee *Acer* morphotype 2 (S153623), EV. Abbreviations: PV, polar view; EV, equatorial view. Scale bars 10 μm (a–c, e, g, i–m, o, p, r–z, bb, dd, ee), 1 μm (d, f, h, n, q, aa, cc)

Ostrya sp.

(Fig. 7q and S 3-Fig. 7m–o)

Remarks: For descriptions and remarks, see Bouchal et al. (2016, p. 34).

Family Fagaceae Dumort., 1829

Genus *Fagus* L., 1753

Fagus sp.

(Fig. 7r–u and S 3-Fig. 8a–f)

Remarks: For descriptions and remarks, see Bouchal et al. (2016, p. 36).

Genus *Quercus* L., 1753.

Remarks:

Denk and Grimm (2009) identified five types of exine sculpturing corresponding to six sections within extant *Quercus* (this has been incorporated in the most recent classification of oaks; Denk et al. 2017): *Quercus* sect. *Cerris* (scattered verrucate), *Quercus* sect. *Ilex* (rodlike, microrugulate), *Quercus* sect. *Cyclobalanopsis* (vertical rodlike), *Quercus* sect. *Protobalanus* (masked rodlike), *Quercus* sect. *Lobatae* and *Quercus* sect. *Quercus* (microverrucate); these distinguishing infrageneric characters are miniscule and not detectable using LM. For the pollen diagram, only size (large or small) was used to categorise oak pollen. *Quercus* sp. 3 was less frequent in the Salihpaşalar section than *Quercus* sp. 1 and 2.

Quercus sp. 1 (*Quercus* sect. *Cerris*)

(Fig. 7v, w and S 3-Fig. 8g–i)

Remarks: For descriptions and remarks, see Bouchal et al. (2016, p. 36, as *Quercus* Group *Cerris*).

Quercus sp. 2 (*Quercus* sect. *Ilex*)

(Fig. 7x, y and S 3-Fig. 8j–l)

Remarks: For descriptions and remarks, see Bouchal et al. (2016, p. 38, as *Quercus* Group *Ilex*).

Quercus sp. 3 (*Quercus* sect. *Quercus*)
(Fig. 7z, aa and S 3-Fig. 8)

Remarks: For descriptions and remarks, see Bouchal et al. (2016, p. 38, as *Quercus* Group *Quercus*).

Family Juglandaceae DC. ex Preleb, 1818
Subfamily Engelhardioideae Iljinsk., 1990

Engelhardioideae gen. indet. 1
(Fig. 7cc–ff and S 3-Fig. 9d–i)

Remarks: For descriptions and remarks, see Bouchal et al. (2016, p. 38, as Engelhardioideae gen. indet.). Engelhardioideae pollen types were combined in the pollen diagram.

Engelhardioideae gen. indet. 2
(Fig. 7bb and S 3-Fig. 9a–c)

Description: Pollen, shape oblate, outline circular to convex triangular in polar view, equatorial diameter 18–22 µm (LM), 17–20 µm (SEM); eutectate, exine 1.0–1.5 µm thick (LM), nexine thinner than sexine; triporate, pore diameter 1–2 µm (LM), ectoporus circular to elliptic, aperture sunken; psilate (LM), nanoechinate (SEM).

Family Myricaceae Rich. ex Kunth, 1817
Genus *Morella* Lour., 1790 vel *Myrica* L., 1753

Morella vel *Myrica* sp.
(Fig. 8c, d and S 3-Fig. 10–i)

Remarks: For descriptions and remarks, see Bouchal et al. (2016, p. 42).

Order Rosales Bercht. et J.Presl, 1820
Family Cannabaceae Martinov, 1820
Genus *Celtis* L., 1753 vel *Pteroceltis* Maxim., 1873

Celtis vel *Pteroceltis* sp.
(Fig. 8e, f and S 3-Fig. 10j–l)

Remarks: For descriptions and remarks, see Bouchal et al. (2017, p. 16).

Family Moraceae Gaudich., 1835/Urticaceae Juss., 1789
Moraceae/Urticaceae gen. indet.
(Fig. 9a–c)

Fig. 9 LM overview (a, d, g, j, m), SEM overview (b, e, h, k, n) and SEM detail (c, f, i, l, o) micrographs of Moraceae, Rosaceae, Lythraceae and Sapindales pollen. a–c Moraceae/Urticaceae gen. indet. (S153623), PV. d–f Rosaceae gen. indet. 1. (S153627), EV. g–i Rosaceae gen. indet. 2. (S153631), polar view. j–l Lythraceae gen. indet. aff. *Ammannia* (S153627), PV. m–o Sapindales fam. et gen. indet. (S153623), (top) PV, (bottom left and right) EV. Abbreviations: PV, polar view; EV, equatorial view (EV). Scale bars, 10 µm (a, b, d, e, g, h, j, k, m, n), 1 µm (c, f, i, l, o)

Description: Pollen, outline circular to convex triangular in polar view, equatorial diameter 12–16 µm (LM), 11–14 µm (SEM); tectate, exine 1–1.5 µm thick (LM); triporate (LM, SEM), pores circular, pore diameter 1.3–1.8 µm (SEM); scabrate (LM), microverrucate, nanoechinate (SEM).

Remarks: Pollen of this type is morphologically (size, aperture, exine sculpture) similar to the Urticaceae *Parietaria* L., e.g. *P. judaica* L., *P. officinalis* L. (Diethart 2005; Halbritter 2015), and Moraceae pollen, e.g. *Morus alba* type of Punt and Malotau (1984).

Family Rosaceae Juss., 1789

Rosaceae gen. indet. 1
(Fig. 9d–f)

Description: Pollen, prolate, outline elliptic in equatorial view, length of polar axis 10–12 µm (LM, SEM), equatorial diameter 7–10 µm (LM, SEM); eutectate, exine 1–1.5 µm thick (LM), tricolporate, ectocolpus length 3/4 to 5/6 of polar axis (SEM); psilate (LM), striate, (SEM), striae parallel to perpendicular to polar axis, striae 0.1–0.2 µm wide (SEM).

Remarks: Rosaceae gen. indet. 1 and 2 were combined in the pollen diagram. Assignment of tricolporate, striate perforate Rosaceae pollen to subfamily or genus level is difficult due to a high degree of morphological overlap (Hebda et al. 1988a, 1988b; Hebda and Chinnappa 1990, 1994, table 1). Reports of Rosaceae pollen from middle Miocene localities of western Turkey are rare (see S 2).

Rosaceae gen. indet. 2
(Fig. 9g–i)

Description: Pollen, prolate, outline circular to lobate in polar view, equatorial diameter 15–18 µm (LM), 13–16 µm (SEM); eutectate, exine 1–1.5 µm thick (LM), tricolporate, colpus membrane granulate, ectocolpus length 3/4 to 5/6 of polar axis (LM, SEM); psilate (LM), striate, perforate (SEM), striae mainly parallel to polar axis, striae 0.1–0.2 µm wide (SEM).

Remarks: Rosaceae gen. indet. 2 differs from Rosaceae gen. indet. 1 by its larger size and by narrower and a higher number of striae.

Family Ulmaceae Mirbel, 1815

Genus *Cedrelospermum* Saporta, 1889

Cedrelospermum sp.

(Fig. 8g, h and S 3-Fig. 10m–o)

Remarks: For descriptions and remarks, see Bouchal et al. (2016, p. 42).

Genus *Ulmus* L., 1753

Ulmus sp.

(Fig. 8i and S 3-Fig. 11a–c)

Remarks: For descriptions and remarks, see Bouchal et al. (2016, p. 44).

Genus *Zelkova* Spach, 1841

Zelkova sp.

(Fig. 8j and S 3-Fig. 11d–f)

Remarks: For descriptions and remarks, see Bouchal et al. (2016, p. 44).

Order Geraniales Juss. ex Bercht., 1892

Family Geraniaceae Juss. 1789

Genus *Erodium* L'Hér., 1789

Erodium sp.

(Fig. 8k and S 3-Fig. 11g–i)

Remarks: For descriptions and remarks, see Bouchal et al. (2016, p. 44).

Order Myrtales Juss. ex Bercht. et Presl, 1820

Family Lythraceae J.St.-Hilaire, 1805

Lythraceae gen. indet. aff. *Ammannia* L., 1753

(Fig. 9j–l)

Description: Pollen, shape prolate, elliptic in equatorial view, length of polar axis 22–27 μm (LM), 21–25 μm (SEM), equatorial diameter 17–21 μm (LM), 14–19 μm (SEM); eutectate, exine 1.5–2 μm thick (LM); tricolporate, ectocolpus with bridge, colpus length 1/2 to 2/3 of polar axis, six pseudocolpi present, pseudocolpus length 1/3 to 1/2 of polar axis (SEM), area surrounding endoporus thickened (LM); rugulate (LM), rugulate to striate, fossulate (SEM), perforate in colpus and pseudocolpus area (SEM),

Fig. 10 LM overview (a, d, g, j, m), SEM overview (b, e, h, k, n) and SEM detail (c, f, i, l, o, p) micrographs of Amaranthaceae, Droseraceae, Polygonaceae, Sapotaceae and Oleaceae pollen. a–c Amaranthaceae gen. indet. 3 (S153636). d–f *Drosera* sp. (S153636). g–i *Persicaria* sp./*Persicarioipollenites pliogenicus* (S153634). j–l Sapotaceae gen. indet. (S153631), EV. m–o Oleaceae gen. indet. 1 (S153623), EV. Abbreviations: PV, polar view; EV, equatorial view. Scale bars, 10 μm (a, b, d, e, g, h, j, k, m, n), 1 μm (c, f, i, l, o)

in equatorial area rugulae/striae partly perpendicular to polar axis.

Remarks: The Lythraceae clade containing the genera *Hionanthera* A.Fern. et Diniz, *Ammannia* L. [including *Nesaea* Comm. ex Kunth (Graham et al. 2005)], *Lawsonia* L. and *Ginoria* Jacq. produce pollen corresponding to the fossil pollen in size, aperture and presence of pseudocolpi (Graham et al. 1985, 1987; Graham et al. 2011). Pollen of *Ammannia* displays closest morphological similarities (pollen shape, length of pseudocolpi) but differs by its exine sculpture; Lythraceae gen. indet. aff. *Ammannia* has much broader/larger rugulae.

Identical pollen has previously been described from Karpatian sediments (late early Miocene) of the Korneuburger Basin, Austria (Hofmann et al. 2002), where this type also co-occurs with pollen of *Decodon*. *Lythraceapollenites bavaricus* Thiele-Pfeiffer (Thiele-Pfeiffer 1980; Stuchlik et al. 2014) corresponds in size, shape, aperture (tricolporate) and presence of pseudocolpi with the present pollen; pollen of extant *Lawsonia*, *Rotala* L. and *Ammannia* has been compared to this fossil species.

Genus *Decodon* J.F.Gmel., 1791

Decodon sp. 1

(Fig. 8l–n and S 3-Fig. 11j–l)

Remarks: For descriptions and remarks, see Bouchal et al. (2016, p. 44).

Decodon sp. 2 (Fig. 8o–q and S 3-Fig. 11m–o)

Description: Pollen, shape prolate, elliptic in equatorial view, length of polar axis 14–18 μm (LM), 14–17 μm (SEM), equatorial diameter 10–14 μm (LM), 10–12 μm (SEM); eutectate, exine 1.5–2 μm thick (LM); tricolporate, in some specimens ectocolpus with bridge, colpus length 1/2 to 2/3 of polar axis (SEM), area surrounding endoporus thickened (LM); psilate (LM), rugulate, fossulate, perforate (SEM).

Remarks: *Decodon* sp. 1 and 2 were combined in the pollen diagram. *Decodon* sp. 2 differs by rugulate sculpture and absence of psilate areas from *Decodon* sp. 1 and corresponds to *Decodon* morphotype 5 of Grímsson et al., 2012, figs. 3D-L and 5J-L).

Order Malvales Juss. ex. Bercht. et Presl, 1820
 Family Malvaceae Juss., 1789
 Subfamily Tilioideae Arn., 1832
 Genus *Tilia* L., 1753/*Intratropipollenites* Pflug et P.W.Thomson in P.W.Thomson et Pflug, 1953

Tilia sp./*Intratropipollenites instructus* (R.Potonié, 1931)
 P.W.Thomson et Pflug, 1953
 (Fig. 8r and S 3-Fig. 12a–c)

Description: For detailed descriptions, see Bouchal et al. (2016, p. 46, as *Tilia* sp.).

Remarks: *Tilia* sp./*I. instructus* falls within the morphological range of this fossil species and strongly resembles pollen of extant *T. platyphyllos* Scop. (Christensen and Blackmore 1988; compare striae on reticulum in S 3-Fig. 12c to Perveen et al. 2004, fig. 4g; Stuchlik et al. 2014; Zhang and Chen 1984). Güner et al. (2017) reported fossil inflorescence bracts of *Tilia* from the Eskihsar and Tinaz lignite mines. Worobiec et al. (2010) indicated a possible interconnection between *I. instructus* and the extinct species *Bytneriophyllum tiliifolium* Givulescu ex Knobloch et Kvaček. Unfortunately, to date, foliage of this species has not been found attached to reproductive structures with in situ pollen to verify this possible association. *B. tiliifolium*, though widely distributed in the Miocene of central and eastern Europe (e.g. Austria, Bulgaria, Czech Republic, Poland, Germany, Switzerland, Hungary, France; see Knobloch and Kvaček, 1965; Worobiec et al. 2010), is absent from the Neogene fossil record of Greece and Turkey (e.g. Gemici et al. 1990, 1991, Gemici and Akgün, 1992, Gemici et al., 1993; Mädler and Steffens 1979; Velitzelos et al. 2014).

Order Sapindales Juss. ex Bercht. et J.Presl, 1820

Sapindales fam. et gen. indet.
 (Fig. 9m–o)

Description: Pollen, shape prolate, elliptic in equatorial view, lobate in polar view, length of polar axis 25–30 µm (LM, SEM), equatorial diameter 15–19 µm (LM, SEM); semitectate, exine 2.5–3 µm thick, sexine thicker than nexine; tricolporate, ectocolpus length 3/4 to 5/6 of polar axis (LM, SEM), endoporus rhombic to circular, costae present, costae reaching polar colpus endings (LM); scabrate (LM), rugulate to striate, fossulate, perforate (SEM).

Remarks: The morphological characteristics of this pollen type are shared by a number of families within the Sapindales (Erdtman 1952), and hence determination down to the family level is not possible.

Fig. 11 LM overview (a, c, e, f, g, h, j, k, m, n, p, t, v, x, z), SEM overview (l, o, q, s, u, w, y, aa) and detail (b, d, i) micrographs of Eucommiaceae, Aquifoliaceae, Asteraceae, Caprifoliaceae and Apiaceae pollen. a, b *Eucommia* sp./*Tricolpopollenites parmarium* (S153623), EV. c, d *Ilex* sp. (S153637), PV. e Asteroidae type 2 (S153623), EV. f Asteroidae type 3 (S153648), EV. g Asteroidae type 1 (S153648), EV. h, i Asteroidae type 5 (S153622), EV. j Asteroidae type 4 (S153622). k, l Cichorioideae gen. indet. (S153623). m *Dipsacus* vel *Cephalaria* (S153641), (left) PV, (right) EV. n, o Apiaceae type 1 (S153623), EV. p, q Apiaceae type 2 (S153623), EV. r, s Apiaceae type 3 (S153623), EV. t, u Apiaceae type 4 (S153641), EV. v, w Apiaceae type 5 (S153623), EV. x, y Apiaceae type 6 (S153622), EV. z–aa Saniculoideae gen. indet. (S153622), EV. Abbreviations: PV, polar view; EV, equatorial view. Scale bars, 10 µm (a, c, f–aa), 1 µm (b, d, i)

Family Sapindaceae Juss., 1789
 Genus *Acer* L., 1753

Acer morphotype 1
 (Fig. 8bb, cc and S 3-Fig. 13g–i)

Description: For detailed descriptions and remarks, see Bouchal et al. (2017, p. 18).

Acer morphotype 2
 (Fig. 8dd, ee and S 3-Fig. 13j–l)

Description: For detailed descriptions and remarks, see Bouchal et al. (2017, p. 21, as *Acer* morphotype 3).

Order Santalales R.Br. ex Bercht. et J.Presl, 1820
 Family Santalaceae R.Br., 1810
 Genus *Arceuthobium* M.Bieb., 1820

Arceuthobium sp.
 (Fig. 6d, f)

Description: Pollen, shape spheroidal, outline circular, diameter (including echini) 27–33 µm (LM), 21–26 µm (SEM); possibly atectate, exine ca 1 µm thick (LM), sexine thinner than nexine; heterocolpate, tricolpate with three pseudocolpi, colpi and pseudocolpi indistinct in LM, ectocolpi length 2/3 of polar axis, pseudocolpi length 1/2 of polar axis (SEM); echinate (LM), echinate, weakly nanoverrucate, perforate (SEM), echini base diameter 0.5–1.5 µm (SEM), echini length 0.9–2.1 µm (SEM), a number of echini have broken off, circular abscission marks visible (Fig. 6f, arrow)

Remarks: The fossil Salihpaşalar specimen corresponds by aperture, size range and exine sculpturing to extant members of *Arceuthobium* (Erdtman 1952; Hawksworth and Wiens 1972), with closest similarities in exine sculpture to *A. pusillum* Peck. Extant members of this genus are parasitic on Pinaceae or Cupressaceae (Hawksworth and Wiens 1972).

Order Caryophyllales Takht., 1967
Family Amaranthaceae Juss., 1789

Amaranthaceae gen. indet. 1
(Fig. 8s, t and S 3-Fig. 12g–i)

Description: Pollen, shape spheroidal, outline circular, diameter 15–20 µm (LM, SEM); eutectate, exine 1.5–2 µm thick (LM), sexine thicker than nexine; pantoporate (45+), pori diameter 0.5–1 µm (SEM), pori sunken, operculate, operculum ornamented with 3–8 nanoechini; scabrate (LM), nanoechinate, perforate (SEM).

Remarks: Amaranthaceae gen. indet. 1, 2 and 3 were combined in the pollen diagram. Amaranthaceae gen. indet. 2 differs from Amaranthaceae gen. indet. 1 and 3 by smaller size, fewer pores and operculi with fewer echini.

Amaranthaceae gen. indet. 2
(Fig. 8u and S 3-Fig. 12d–f).

Description: For detailed descriptions and remarks, see Bouchal et al. (2016, p. 50, as Amaranthaceae vel Chenopodiaceae gen. indet. 2).

Amaranthaceae gen. indet. 3
(Fig. 10g–i and S 3-Fig. 12j–l)

Description: Pollen, shape spheroidal, outline circular, diameter 10–15 µm (LM, SEM); eutectate, exine 1.5–2 µm thick (LM), sexine thicker than nexine; pantoporate (18+), pori diameter 1–1.5 µm (SEM), pori sunken, operculate, operculum ornamented with 15–25 nanoechini; scabrate (LM), nanoechinate, perforate (SEM).

Remarks: Amaranthaceae gen. indet. 3 differs by its smaller size and operculi with a higher number of nanoechini from Amaranthaceae gen. indet. 1 and 2. Strong morphological similarities between the Ranunculaceae *Thalictrum* L. (Clarke et al. 1991) and the fossil species *Thalictrumpollis thalictroides* Stuchlik (Stuchlik et al. 2009) can be observed using LM. Using SEM Amaranthaceae pollen reveals nanoechinate and perforate exine sculpturing, whereas *Thalictrum* lacks perforations and its nanoechini are more evenly spaced (compare Clarke et al. 1991).

Family Caryophyllaceae Juss., 1789
Caryophyllaceae gen. indet. 1
(Fig. 8v, w and S 3-Fig. 12m–o)

Description: Pollen, shape spheroidal, outline polygonal to weakly circular, diameter 30–35 µm (LM, SEM); eutectate, exine 2–3 µm thick (LM), nexine thinner than sexine,

Fig. 12 LM overview (a, d, g, j, n), SEM overview (b, e, h, k, o) and SEM detail (c, f, i, l, m, p, q) micrographs of Oleaceae, Asteraceae, Adoxaceae and Caprifoliaceae pollen. a–c *Oleaceae* gen. indet. 2 (S153623), PV. d–f. *Oleaceae* gen. indet. 3 (S153623), EV, (f) brochi with free-standing columellae, g–i *Artemisia* sp. (S153623), (g, h) EV. j–m *Viburnum* sp. (S153631), EV, free-standing (j) colpus detail. n–q *Valeriana* sp. (S153636), EV, (m) exine sculpture detail, (n) colpus detail. Abbreviations: PV, polar view; EV, equatorial view. Scale bars, 10 µm (a, b, d, e, g, h, j, k, n, o), 1 µm (c, f, i, l, m, p, q)

pantoporate, pori diameter 4–7 µm (SEM), number of pori 15–20, pori sunken; scabrate (LM), nanoechinate, perforate (SEM), nanoechini evenly spaced (SEM).

Caryophyllaceae gen. indet. 2
(Fig. 8x, y and S 3-Fig. 13a–c)

Description: Pollen, shape spheroidal, outline polygonal to weakly circular, diameter 29–32 µm (LM, SEM); eutectate, exine 3–4 µm thick (LM), nexine thinner than sexine, pantoporate, pori diameter 3.5–4.5 µm (SEM), number of pori 10–15 (LM), pori sunken, operculate (SEM); scabrate (LM), nanoechinate, perforate (SEM), nanoechini evenly spaced, operculum with weak ornamentation (SEM).

Remarks: Caryophyllaceae gen. indet. 1 and 2 were combined in the pollen diagram. Caryophyllaceae gen. indet. 2 differs from Caryophyllaceae gen. indet. 1 by smaller pores, smaller perforations and fewer apertures. Pollen of this family has been reported previously from YB (Table 2).

Family Droseraceae Salisb., 1808
Genus *Drosera* L., 1753

Drosera sp.
(Fig. 10a–c)

Description: Pollen, tetrahedral tetrad, single pollen shape spheroidal to oblate, tetrad diameter 80–100 µm (LM), single pollen diameter 45–65 µm (LM); atectate, nexine 1.5–2 µm thick on distal face (LM); aperture indistinct, pores in equatorial area; echinate, microechinate (LM, SEM), echini length 2.5–3.5 µm (SEM), microechini length 0.7–1 µm (SEM).

Remarks: Extant pollen of *Drosera rotundifolia* L. (Halbritter et al. 2012) and the *D. rotundifolia* type of Punt et al. (2003) correspond the Salihpaşalar specimen by the presence of echini and microechini.

Family Polygonaceae Juss., 1789
Genus *Persicaria* (L., 1753) Mill., 1754/*Persicarioipollenites* Krutzsch 1962 emend. Krutzsch, 1966

Persicaria sp./*Persicarioipollenites pliogenicus* Krutzsch, 1962
(Fig. 10d–f)

Description: Pollen, shape spheroidal, outline circular, diameter 60–70 μm (LM, SEM); semitectate, exine 5–6 μm thick (LM), sexine thicker than nexine; pantoporate, pori diameter 2–3 μm (SEM), lumen containing a porus slightly smaller; reticulate, +/- homobrochate (LM, SEM), lumen with free-standing columellae (clava-like), muri duplicolumellate (SEM), porus membrane granulate (Fig. 10f)

Remarks: *Persicaria* sp. corresponds (reticulate, pantoporate, duplicolumellate muri) to pollen of the extant genus, with closest similarities to the *Polygonum persicaria* type of Van Leeuwen et al. (1988). Akgün and Akyol (1999, fig. 20.40) figured a morphologically similar grain from the Menderes Graben, Turkey.

Genus *Rumex* L., 1753

Rumex sp.

(Fig. 8z, aa and S 3-Fig. 13d–f)

Description: For detailed descriptions and remarks, see Bouchal et al. (2016, p. 52).

Order Ericales Bercht. et J.Presl, 1820

Family Sapotaceae Juss., 1789

Sapotaceae gen. indet.

(Fig. 10j–l)

Description: Pollen, shape prolate, outline elliptic in equatorial view, length of polar axis 30–40 μm (LM), 24–32 μm (SEM), equatorial diameter 25–34 μm (LM), 20–28 μm (SEM); eutectate, exine 2–3.5 μm thick (LM), nexine thinner than sexine, nexine thickened in aperture area (costa), costa not reaching apical ends of colpus; tetracolporate, ectocolpus length 3/4 to 5/6 of length of polar axis, endoporus quadrangular, framed by costa; scabrate (LM), nanoverrucate, perforate (SEM), nanoverrucae and perforations evenly spaced.

Remarks: Extant Sapotaceae pollen has been studied extensively by Harley (1991); perforate, nanoverrucate (finely granulate in Harley 1991) exine sculpture, corresponds to Harley's pollen type IA, which is found in several genera of tribus Sapoteae [e.g. *Mimusops* L., *Paysonia* A.de Candolle, *Madhuca* Hamilton ex J.F.Gmelin (Harley 1991; Swenson and Anderberg 2005)]; extant genera of this tribus have a palaeotropical distribution (Pennington 2004). Sapotaceae pollen differing in aperture has been reported from the YB (Bouchal et al. 2017, p. 21, pl. 11.8–10).

Order Garryales Mart., 1835

Family Eucommiaceae Engl., 1907

Fig. 13 LM overview (a, e, h, k, n), SEM overview (b, f, i, l, o) and SEM detail (c, g, j, m, p) micrographs of Asteraceae, Araliaceae and undetermined pollen. a–d *Centranthus* sp. (S153631), PV, (c) exine sculpture detail, (d) colpus membrane detail. e–g Araliaceae gen. indet. (S153641), EV. h–j Pollen type 1 (S153623), (h, i) pollen agglomeration, (j) exine sculpture detail. k–m Pollen type 2 (S153632), EV. n–p Pollen type 3 (S153637), PV. Abbreviations: PV, polar view; EV, equatorial view. Scale bars, 10 μm (a, b, e, f, h, i, k, l, n, o), 1 μm (c, g, j, m, p)

Genus *Eucommia* Oliv., 1895/*Tricolpopollenites* Pflug et P.W.Thomson in P.W.Thomson et Pflug, 1953

Eucommia sp./*Tricolpopollenites* *parmularius* (R.Potonié, 1935) P.W.Thomson et Pflug, 1953

(Fig. 11a–b and S 3-Fig. 13m–o)

Description: For detailed descriptions and remarks, see Bouchal et al. (2016, p. 54, as *Eucommia* sp.).

Order Lamiales Bromhead, 1838

Family Oleaceae Hoffmanns. et Link, 1809

Remarks: Pollen of extant Oleaceae show a high degree of morphological variability and overlap [e.g. *Olea* (Nilsson 1988); *Fraxinus* L. (compare Renault-Miskovsky et al. 1976; Barento et al. 1987; Punt et al. 1991; Guo et al. 1994; Jones et al. 1995; Li et al. 2010; Miyoshi et al. 2011)]. This makes identification of dispersed Oleaceae pollen to the genus level difficult. Oleaceae gen. indet. 1, 2 and 3 were combined in the pollen diagram.

Oleaceae gen. indet. 1

(Fig. 10m–o)

Description: Pollen, shape spheroidal, outline circular in equatorial view, lobate to circular polar view, length of polar axis 20–26 μm (LM), 22–25 μm (SEM), equatorial diameter 17–23 μm (LM), 15–19 μm (SEM); atectate, exine 2–2.5 μm thick (LM), nexine thinner than sexine; tricolporate, ectocolpus length 2/3 to 3/4 of polar axis (LM, SEM); reticulate (LM, SEM), muri width 0.8–1.2 μm (SEM), muri crested with distinct ridges and nanoechini, lumina of irregular shape and size (SEM).

Remarks: Muri crested with distinct ridges and nanoechini are the defining characters of Oleaceae gen. indet. 1. Extant *Olea* L. and *Chionanthus* L. (Renault-Miskovsky et al. 1976; Barento et al. 1987; Nilsson 1988; Punt et al. 1991; Guo et al. 1994; Sachse 2001) produce pollen of similar morphology. Similar pollen has previously been reported from the YB (Bouchal et al. 2016, p. 56, fig. 22D–F, as Oleaceae gen. indet. 4; Bouchal et al. 2017, p. 25, pl. 12.7–9, as Oleaceae gen. indet. 4).

Oleaceae gen. indet. 2

(Fig. 12a–c)

Description: Pollen, shape prolate, outline elliptic in equatorial view, length of polar axis 22–27 μm (LM), 22–25 μm (SEM), equatorial diameter 17–23 μm (LM), 15–19 μm (SEM); atectate, exine 2–2.5 μm thick (LM), nexine thinner than sexine; tricolporate, ectocolpus length 2/3 to 3/4 of polar axis (LM, SEM); reticulate (LM, SEM), muri width 0.8–1.2 μm (SEM), muri with weak perpendicular ridges, lumina of irregular shape and size, lumina psilate (SEM).

Remarks: Oleaceae gen. indet. 2 can be distinguished from Oleaceae gen. indet. 1 and 3 by its perpendicular ridged reticulum. Similar pollen has previously been reported from the YB (Bouchal et al. 2016, p. 56, Fig. 21J–L, as Oleaceae gen. indet. 2) and from late Miocene localities of northern Italy (Sachse 2001). Similar pollen are produced by extant *Phillyrea angustifolia* L. (Renault-Miskovsky et al. 1976; Sachse 2001), *Linociera obtusifolia* (Lam.) H. Perrier and *Noronhia linocerioides* H. Perrier (Cerceanu-Larrivall et al. 1984).

Oleaceae gen. indet. 3
(Fig. 12d–f)

Description: Pollen, shape spheroidal, outline circular in equatorial view, lobate to circular in polar view, length of polar axis 21–25 μm (LM), 20–23 μm (SEM), equatorial diameter 20–24 μm (LM), 19–22 μm (SEM); atectate, exine 2.5–3 μm thick (LM), nexine thinner than sexine; tricolporate, ectocolpus length 2/3 to 3/4 of polar axis (LM, SEM); reticulate (LM, SEM), muri width 0.8–1.2 μm (SEM), muri with weak nanoechini, lumina of irregular shape and size, lumina with freestanding columellae (SEM).

Remarks: Oleaceae gen. indet. 3 is defined by muri crested with weak nanoechini and wide lumina with freestanding columellae. Similar pollen has been reported from the YB (Bouchal et al. 2016, p. 56, fig. 21A–C, as Oleaceae gen. indet. 3, differing by psilate lumina; Bouchal et al. 2017, p. 23, pl. 12.4–6, as Oleaceae gen. indet. 3, freestanding columellae visible). Extant *Olea*, *Fontanesia* Labillardière and *Osmanthus* Loureiro (Renault-Miskovsky et al. 1976; Nilsson 1988; Guo et al. 1994; Sachse 2001; Li et al. 2010) produce pollen with nanoechinate muri.

Campanulids
Order Aquifoliales Senft, 1856
Family Aquifoliaceae Bercht. et J. Presl, 1825
Genus *Ilex* L., 1753

Ilex sp.
(Fig. 11c, d and S 3-Fig. 14a–c)

Remarks: For detailed descriptions and remarks, see Bouchal et al. (2017, p. 25).

Order Asterales Link, 1829
Family Asteraceae Berchthold et Presl, 1820
Subfamily Asteroideae Lindl

Asteroideae type 1
(Fig. 11g and S 3-Fig. 14d–f)

Remarks: For detailed descriptions and remarks, see Bouchal et al. (2017, p. 25, as Asteroideae type 1). Asteroideae types 1 to 5 clearly belong to this subfamily (compare Punt and Hoen 2009); due to poor preservation (folded, broken, deformed grains), the encountered echinate pollen cannot be assigned to particular genera. The here used types are purely artificial and of no taxonomic value. *Artemisia* and Asteroideae types 1 to 5 were combined in the pollen diagram.

Asteroideae type 2
(Fig. 11e and S 3-Fig. 14g–i)

Description: Pollen, shape spheroidal, outline circular in equatorial view, length of polar axis 15–20 μm (LM, SEM), equatorial diameter 15–20 μm (LM, SEM); exine including echini 3–4 μm thick (LM), sexine thicker than nexine; tricolporate, ectocolpus length 1/2 to 2/3 of polar axis; echinate (LM), echinate, perforate (SEM), echinus base diameter 2–2.5 μm (SEM), echini acute and short, echinus length 1–2 μm (SEM), perforations extending to upper half of echini, echini densely spaced.

Remarks: Asteroideae type 2 is defined by small size, densely spaced broad based echini and small perforations.

Asteroideae type 3 (Fig. 11f and S 3-Fig. 14j–l)

Description: Pollen, shape prolate, outline elliptic in equatorial view, length of polar axis 20–30 μm (LM, SEM), equatorial diameter 15–20 μm (LM, SEM); exine including echini 2–3 μm thick (LM), sexine thicker than nexine; tricolporate, ectocolpus length 1/2 to 2/3 of polar axis; echinate (LM), echinate, perforate (SEM), echinus base diameter 1–1.5 μm (SEM), echini acute and short, echinus length 1–1.5 μm (SEM), perforations extending to lower third of echini, echini widely spaced.

Remarks: Asteroideae type 3 differs by thinner exine and small, more widely spaced echini from the remaining four Asteroideae pollen types.

Asteroideae type 4
(Fig. 11j and S 3-Fig. 14 m–o)

Remarks: For detailed descriptions and remarks, see Bouchal et al. (2016, p. 58, as Asteroideae type 2).

Asteroideae type 5
(Fig. 11h, i and S 3-Fig. 15a–c)

Description: Pollen, shape prolate, outline elliptic in equatorial view, length of polar axis 30–35 μm (LM, SEM), equatorial diameter 25–30 μm (LM, SEM); exine including echini 3.5–5 μm thick (LM), sexine thicker than nexine; tricolporate, ectocolpus length 2/3 to 3/4 of polar axis; echinate, perforate (LM, SEM), echinus base diameter 3–4 μm (SEM), echini blunt and short, echinus length 1.5–2 μm (SEM), perforations extending to upper third of echini.

Remarks: The characters defining Asteroideae type 4 are distinctly large perforations (visible in LM, Fig. 11h), a thick exine and blunt echini, clearly setting it apart from the other Asteroideae pollen types.

Genus *Artemisia* L., 1753

Artemisia sp.
(Fig. 12g–i and S 3-Fig. 15d–f)

Description: Pollen, shape prolate, pollen outline circular to lobate in polar view, equatorial diameter 10–15 μm (LM, SEM), polar axis 12–20 μm (LM, SEM); tectate; tricolpate, ectocolpus length 3/4 to 5/6 of polar axis (SEM); scabrate (LM), nanoechinate, echini densely spaced (SEM).

Remarks: Pollen of *Artemisia* has rarely been reported from middle Miocene localities of western Turkey: *Artemisia* (Jiménez-Moreno 2005; Kayseri-Özer et al. 2014b).

Subfamily Cichorioideae Chevall., 1828

Cichorioideae gen. indet.
(Fig. 11k, l and S 3-Fig. 15g–j)

Description: Pollen, shape spheroidal, outline polygonal, pollen diameter 30–40 μm (LM, SEM); lophate, exine including lophae and echini 3–6 μm thick (LM), nexine thinner than sexine; tricolporate, colpus membrane granulate, lacune forming bridge over edoporus; lophate, echinate, perforate (LM, SEM), echini acute, echinus base diameter 0.8–1.3 μm (SEM, LM), echinus height 1.5–2 μm (SEM), echini without perforations, echini present only on lophae, lophae perforate, interporal lacuna perforate, abporal lacuna psilate.

Remarks: Cichorioideae gen. indet. can be assigned to the *Lactuca sativa* type of Blackmore (1984) owing to the position and presence of perforate lacunae.

Order Dipsacales Juss. ex Bercht. et J.Presl, 1820
Family Adoxaceae E.Mey., 1839

Genus *Viburnum* L., 1753

Viburnum sp.
(Fig. 12j–m)

Description: Pollen, shape prolate, outline elliptic, length of polar axis 28–33 μm (LM, SEM), equatorial diameter 18–23 μm (LM, SEM); semitectate, exine 2–3 μm thick (LM), sexine thicker than nexine; tricolporate, porus diameter 2–3 μm (SEM), endoporus circular, colpus length 2/3 to 3/4 of polar axis, costae reaching polar colpus endings; reticulate, +/- homobrochate in mesocolpium and polar areas, reticulum condensed in aperture areas (SEM), lumen with freestanding columellae (SEM), muri smooth and elevated by columellae.

Remarks: *Viburnum* sp. corresponds in its morphological characters (tricolporate apertures, reticulate tectum, reticulum condensed in aperture areas, lumina with freestanding columellae) to the extant pollen of this genus (Maciejewska 1997), with closest similarities to pollen “class A” of Donoghue (1985), which is commonly found in this genus.

Family Caprifoliaceae Juss., 1789

Subfamily Dipsacoideae Eaton

Genus *Dipsacus* L., 1753/*Cephalaria* Schrad. 1818

Dipsacus vel *Cephalaria* sp.
(Fig. 11m)

Remarks: For detailed descriptions and remarks, see Bouchal et al. (2017, p. 27).

Subfamily Valerianoideae (Valerianaceae Batsch, 1802)
Genus *Valeriana* L., 1753

Valeriana sp.
(Fig. 12n–q)

Description: Pollen, shape prolate, length of polar axis 35–47 μm (LM, SEM), equatorial diameter 30–38 μm (LM, SEM); eutectate, exine 3–4 μm thick including echini (LM), sexine thicker than nexine; tricolpate, (LM, SEM), ectocolpus length 2/3 to 3/4 of polar axis; microechinate (LM), microechinate (more numerous), nanoechinate, perforate (SEM), area surrounding microechini slightly raised (weak verrucae), micro- and nanoechini blunt (obtuse), colpus membrane nanoechinate (SEM).

Remarks: The available specimen corresponds by its exine architecture and microechinae situated on weak verrucae to the

Valeriana officinalis type of Clarke and Jones (1977) and the *Valeriana* pollen type I of Clarke (1978). Previous reports of Valerianoideae pollen from middle Miocene localities of western Turkey: Valerianaceae (Yavuz-Işık 2007; Yavuz-Işık et al. 2011).

Genus *Centranthus* DC., 1805

Centranthus sp.

(Fig. 13a–d)

Description: Pollen, outline in polar view lobate to circular, equatorial diameter 30–37 μm (LM, SEM); eutectate, exine 2.5–3.5 μm thick (LM), sexine thicker than nexine; tricolpate, ectocolpus length 3/4 to 5/6 of polar axis, sunken, colpus ends acute; microechinate (LM), microechinate (more numerous), nanoechinate, perforate (SEM), micro- and nanoechini acute, colpus membrane covered with acute microechini.

Remarks: *Centranthus* sp. corresponds in several characteristics (exine architecture, exine ornamentation, aperture, microechinate colpus membrane) to extant *Centranthus ruber* type of Clarke and Jones (1977) and *Centranthus* of Clarke (1978).

Order Apiales Nakai, 1930

Family Apiaceae Lindl., 1836

Apiaceae type 1

(Fig. 11n, o and S 3-Fig. 15k–n)

Description: Pollen, shape prolate, length of polar axis 19–22 μm (LM, SEM), equatorial diameter 10–14 μm (LM, SEM); eutectate, exine 1–1.5 μm thick in apex area, 2–2.5 μm in mesocolpium area (LM), sexine thicker than nexine, outer contour convex, inner contour weakly concave; tricolporate, slit-like ectocolpus with bridge in porus area (LM, SEM), ectocolpus length 1/2 to 2/3 of polar axis, endoporus circular; scabrate (LM), microrugulate, fossulate, perforate (SEM), sculpturing in aperture area pronounced rugulate, fossulate (loosely packed), sculpturing in mesocolpium and apex area more perforate (more densely packed).

Remarks: Apiaceae types 1 to 6 were combined in the pollen diagram. For the morphological description of Apiaceae type pollen, the nomenclature of Punt (1984) is used. Apiaceae type 1 has strong morphological similarities (colpus length, exine thickened in mesocolpium) to the *Conium* type of Beug (2004), with closest similarities to *Falcaria vulgaris* Bernh. (Beug, 2004, plate 23, figs 19–20), and the *F. vulgaris* type of Punt (1984) but differs by its smaller size.

Apiaceae type 2

(Fig. 11p, q and S 3-Fig. 15o–r)

Description: Pollen, shape prolate, length of polar axis 17–19 μm (LM, SEM), equatorial diameter 8–10 μm (LM, SEM); eutectate, exine 1–1.5 μm thick in apex area, 2–2.5 μm in mesocolpium area (LM), sexine thicker than nexine, outer contour convex, inner contour straight; tricolporate, slit-like ectocolpus with (weakly raised) bridge in porus area (LM, SEM), ectocolpus length 3/4 to 5/6 of polar axis, endoporus circular; scabrate (LM), microrugulate, fossulate, perforate (SEM).

Remarks: This pollen type falls in the morphological range of *Sison amomum* type of Punt (1984) and *Berula erecta* group of Beug (2004), with closest affinities (size) to *S. amomum* L. (see pl. 25, figs. 35–36 in Beug 2004).

Apiaceae type 3

(Fig. 11r, s and S 3-Fig. 16a–d)

Description: Pollen, shape prolate, length of polar axis 24–28 μm (LM, SEM), equatorial diameter 13–17 μm (LM, SEM); eutectate, exine 2–2.5 μm thick in apex area (LM), nexine thickened in porus area, in all other areas sexine either same thickness as nexine or thicker than nexine, outer contour convex, inner contour distinctly concave curved in porus area; tricolporate, slit-like ectocolpus (LM, SEM), ectocolpus length 3/4 to 5/6 of polar axis, endoporus elliptic; scabrate (LM), microrugulate, fossulate, perforate (SEM), sculpturing in mesocolpium and aperture area loosely packed, sculpturing in apex area more densely packed (SEM).

Remarks: Apiaceae type 3 has strong morphological similarities to the *Oenanthe fistulosa* type of Punt (1984) and to *O. fistulosa* L. in Beug (2004, pl. 23, figs. 10–12).

Apiaceae type 4

(Fig. 11t, u and S 3-Fig. 16e–h)

Description: Pollen, shape prolate, length of polar axis 16–19 μm (LM, SEM), equatorial diameter 9–11 μm (LM, SEM); eutectate, exine 1.5–2 μm thick in apex area (LM), outer contour convex, inner contour not detectable; tricolporate, slit-like ectocolpus (LM, SEM), ectocolpus length 3/4 to 5/6 of polar axis; scabrate (LM), microrugulate, fossulate, perforate (SEM), sculpturing in mesocolpium and aperture area loosely packed, sculpturing in apex area more densely packed, perforate (SEM).

Remarks: Apiaceae type 4 is poorly preserved, its dimensions (size, colpus length) are similar with Apiaceae type 3 but differences in exine sculpturing set this type apart from co-occurring pollen types.

Apiaceae type 5

(Fig. 11v, w and S 3-Fig. 16i–l)

Description: Pollen, shape prolate, length of polar axis 23–26 µm (LM, SEM), equatorial diameter 11–14 µm (LM, SEM); eutectate, exine 1.5–2 µm thick (LM), sexine thicker than nexine, outer contour straight, inner contour weakly convex; tricolporate, slit-like ectocolpus with bridge in porus area (LM, SEM), ectocolpus length 3/4 to 5/6 of polar axis, endoporus elliptic; scabrate (LM), microrugulate, fossulate, perforate (SEM).

Remarks: Apiaceae type 5 has some similarities (long colpus, elliptic endoporus) with the *Apium inundatum* type of Punt (1984).

Apiaceae type 6
(Fig. 11x, y and S 3-Fig. 16m–p)

Description: Pollen, shape prolate, length of polar axis 19–24 µm (LM, SEM), equatorial diameter 11–14 µm (LM, SEM); eutectate, exine 1.5–2 µm thick in apex area (LM), outer contour straight, inner contour weakly concave; tricolporate, slit-like ectocolpus (LM, SEM), ectocolpus length 3/4 to 5/6 of polar axis, endoporus rectangular; scabrate (LM), microrugulate, fossulate, perforate (SEM), sculpturing in mesocolpium and aperture area loosely packed, sculpturing in apex area more densely packed (perforate).

Remarks: Apiaceae type 6 has similar dimensions (size, colpus length) with Apiaceae type 5 but differs in its exine sculpturing.

Subfamily Saniculoideae Burnett

Saniculoideae gen. indet.
(Fig. 11z, aa and S 3-fig. 16q–t)

Description: Pollen, shape prolate, length of polar axis 40–44 µm (LM, SEM), equatorial diameter 17–20 µm (LM, SEM); eutectate, exine 1.5–2 µm thick (LM), sexine thicker than nexine, outer contour convex to straight, inner contour distinctly concave in porus area; tricolporate, slit-like ectocolpus (LM, SEM), ectocolpus length >5/6 of polar axis, band-like costae around the equator (endocingulum); scabrate (LM), microrugulate, fossulate, perforate (SEM).

Remarks: Saniculoideae gen. indet. corresponds (inner and outer contour, aperture, sculpturing) to *Astrantia (major)* type pollen (e.g. Cerceau-Larrivall et al. 1984; Punt 1984; Beug 2004). Pollen of this subfamily has previously been reported from the YB (Bouchal et al. 2016, 2017).

Family Araliaceae Juss., 1789

Araliaceae gen. indet.
(Fig. 13e–g)

Description: Pollen, shape prolate, outline in equatorial view elliptic, length of polar axis 25–30 µm (LM, SEM), equatorial diameter 16–22 µm (LM, SEM); eutectate, exine 2.5–3.5 µm thick (LM), sexine thicker than nexine; tricolporate, pori sunken, operculate, ectocolpus length 2/3 to 3/4 of polar axis, endoporus circular, indistinct costae present; scabrate (LM), microreticulate (SEM), lumina condensed in colpus area.

Remarks: Araliaceae gen. indet. has characteristics (exine sculpturing, aperture) commonly present in genera of this family, e.g. *Aralia* L., *Panax* L. (Wen and Nowicke 1999).

Incerta sedis

Remarks: Pollen of uncertain determination was not included in the pollen diagram.

Pollen type 1
(Fig. 13h–j)

Description: Pollen agglomeration, pollen outline +/- circular in polar view, equatorial diameter 10–15 µm (LM, SEM); tectate; tri- to tetra porate, porus diameter 1.5–2 µm (LM, SEM); psilate (LM), nanoechinate, perforate (SEM).

Remarks: This pollen agglomeration consists of a single type of densely packed pollen grains and pollenkitt suggesting this is the content of an immature pollen sack. Nanoechinate, porate pollen is produced by a number of families (e.g. Betulaceae, Myricaceae, Juglandaceae, Moraceae and Urticaceae); further determination is not possible owing to the immature state of the pollen.

Pollen type 2
(Fig. 13k–m)

Description: Pollen, shape spheroidal, outline in equatorial view circular, length of polar axis 17–20 µm (LM, SEM), equatorial diameter 15–18 µm (LM, SEM); eutectate, exine 1–1.5 µm thick (LM), sexine thicker than nexine; tricolporate to tricolporidate, colpus sunken, ectocolpus length 2/3 to 3/4 of polar axis, indistinct endoporus; psilate (LM), perforate, microfossulate (SEM), fossule more frequent in colpus area (SEM).

Pollen type 3
(Fig. 13n–p)

Description: Pollen, outline circular to lobate in polar view, equatorial diameter 19–23 µm (LM, SEM); tectate, exine 1–1.5 µm thick (LM); pentacolpate, ectocolpus length 1/3 to 1/2 of equatorial diameter, colpus membrane granulate (LM, SEM); psilate (LM), granulate (SEM)

Discussion

Palynoflora and pollen zones of the Salihpaşalar lignite mine section

The most frequently observed palynomorphs of the Salihpaşalar section belong to Fagaceae (14.5–47.5%) and bisaccate gymnosperm pollen (8.75–34.5%); through the entire section arboreal pollen (AP) (73–94%) is distinctly more frequent than non-arboreal pollen (NAP).

The composition of the palynofloras of the Salihpaşalar section is rather homogenous, but two pollen zones can be distinguished.

Pollen Zone (PZ) 1 is characterised by a higher abundance of spores (7.75–14%) and azonal elements (*Decodon* 4.5–12.75%) and has previously been reported from the Eskihişar and Tınaz mine sections by Bouchal et al. (2016, 2017). At the Salihpaşalar mine, PZ1 is restricted to the lower part of the sampled section (S153622–S15327) comprising the thickest lignite seam, its intercalated sediments and the underlying micaceous siltstones. PZ 1 mainly concurs in its composition with PZ 2, differing only in the presence of *Lycopodium*, *Lycopodiella*, *Selaginella*, *Pilularia*, *Tsuga* and *Drosera*.

PZ 2 is confined to the upper part of the section overlying the main lignite seam consisting of clayey limestones and marls intercalated by thin lignite beds (samples S15329–S15346). In this zone, occasional abundance spikes of algal cysts (> 20%, in S15329 and S15339) and Apiaceae (9.5% in S15338) are recorded and spores are less frequent (0.5–2.75%). Pollen of *Buxus*, papillate Cupressaceae, *Ilex*, *Persicaria*, Sapotaceae, Valerianoideae and *Viburnum* have only been encountered in PZ 2.

Comparing the palynoassemblages of the YB

Palynofloras from different strata and localities in the YB, most of them belonging to the Turgut and Sekköy members, have been the focus of a high number of studies (this study; Nakoman 1967; Benda 1971; Gemici et al. 1990; Erdei et al. 2002; Jiménez-Moreno 2005; Akgün et al. 2007; Yavuz-Işık et al. 2011; Koç, 2017; Bouchal et al. 2016, 2017). Most of these studies agree that Fagaceae and Pinaceae are the most taxonomically diverse and abundant families in the palynofloras of the Turgut and Sekköy members (Table 2). This study and Bouchal et al. (2016, 2017) distinguished four pollen zones for sections of the YB lignite mines (Eskihişar, Tınaz, Salihpaşalar): (i) PZ 1 is mainly dominated by fern spores (S 4, abundances ranging from < 10–60%) and azonal elements (e.g. *Alnus*) and is restricted to the lignite seams and intercalated and underlying layers. Hence, in this PZ, a strong facies signal is seen rather than a stratigraphical one. Gemici et al. (1990, Table 1) report fern spore abundances of > 80% and

Yavuz-Işık et al. (2011, samples E in fig. 2; spores were not investigated in this study) report *Alnus* pollen values of < 40% for their samples from Eskihişar; this would possibly place these samples in PZ 1. (ii) In PZ 2, zonal AP taxa are most diverse and abundant (e.g. Pinaceae, Fagaceae, Juglandaceae, *Ulmaceae*) while the herbaceous component is diverse but of low abundance. In the Eskihişar, Tınaz and Salihpaşalar mines, this PZ is present in the first 10–20 m of marls and limestones overlying the lignite seams. A similar signal is reported from samples from Çatakağyaka (ca 12 km southeast of Tınaz) by Jiménez-Moreno (2005, samples 1 and 2 in fig. 4.77) and Yavuz-Işık et al. (2011, samples Ç in fig. 3). Bouchal et al. (2017) reported a (iii) transitional zone between PZ 2 and PZ 3 for their Tınaz section. Here, the ratio between AP and non-AP fluctuates strongly and diversity and abundance of herbaceous taxa increases while AP taxa decrease (S 4). Possibly, the upper part of the Eskihişar section of Bouchal et al. (2016, samples S153582–S153593 in fig. 2) could belong to this PZ, because of an abundance peak of Amaranthaceae and Apiaceae. Similar increased abundance of herbaceous taxa has been reported from Çatakağyaka (< 25% NAP, Jiménez-Moreno 2005, sample 3 in fig. 4.77) and Yeni Eskihişar 1 (< 30%, Yavuz-Işık et al. 2011, sample Y in fig. 3). It is important to note that these similarities reflect similar facies but not necessarily same age. (iv) In PZ 3, present in a single sample from the Tınaz section of Bouchal et al. (2017), AP abundance and diversity have further declined and a value of < 20% of AP is reported (S 4).

Only rare accessory elements, namely spores of *Lycopodiella*, *Selaginella*, *Pilularia* and pollen of *Tsuga* (nonechinate type), *Smilax*, Moraceae vel Urticaceae, *Drosera*, *Persicaria*, *Artemisia*, *Viburnum*, *Valeriana*, *Centranthus* and Araliaceae are confined to the Salihpaşalar section. Among these taxa, many are typical elements of lake shores and wetlands (e.g. *Pilularia*, *Valeriana*, *Drosera* and *Ammania*). Likewise, a number of accessory elements are only reported from Eskihişar (*Succisa*, *Convolvulus*, *Erica*, Ericaceae gen. indet., *Apios*, *Ludwigia*, aff. *Ailanthus*) and Tınaz [Ajugoideae gen. indet., Campanuloideae gen. indet., *Scabiosa*, *Picrasma*, *Tsuga* (echinate type)].

Noteworthy is also the presence/absence of some of these accessory elements. While documented by Gemici et al. (1990), the presence of the rare and distinct Sapotaceae pollen type could not be verified in samples of the Eskihişar mine investigated by Benda (1971, “Eskihişar Pollenbild”) and Bouchal et al. (2016), but single occurrences are documented for Tınaz and Salihpaşalar (this study; Bouchal et al. 2017). Another example is *Buxus* pollen, which is absent from the Tınaz section but documented for Eskihişar and Salihpaşalar, while leaf remains of *Buxus pliocenica* Saporta et Marion are reported from Tınaz and Eskihişar (Bouchal et al. 2016, 2017; Güner et al. 2017).

Depositional environment

The alternating 19-m sequence of pelitic sediment (limestones and marls) intercalated with lignites at the Salihpaşalar lignite mine shows no signs of deltaic sedimentation (absence of channelfills and coarse-grained sediments). The formation of lignite at the margin of the YB was most likely controlled by water table fluctuations within the palaeo-lake, either by transient subsidence of the basin or change in fluvial water supply. During a deepening phase (more subsidence/higher water input) of the palaeo-lake, the pelitic limestones and marls were deposited; coal swamps probably developed when the water table receded to a level that still provided a water-saturated lake margin. In the first few centimetres (1–5 cm) of limestone or marl beds following a lignite bed, poorly preserved monocotyledon root horizons (affinities to *Phragmites* or *Typha*) were observed. These probably represent the development of a reed belt that developed in response to the flooding of the shallow, swampy palaeo-lake margin areas. The overlying marls and pelitic limestones do not contain such root horizons, indicating a further deepening of the palaeo-lake. Summarising, the deposits of the Salihpaşalar section accumulated in a marginal part of the Yatağan palaeo-lake. No clastic payload incoming from a fluvial system affected the sedimentation. Whether cosmic cyclicities or subsidence did lead to the alternating lignite and limestone pattern of the Salihpaşalar section has not been the focus of this study. Future geological investigations on more complete sections (e.g. drill cores) of the main YB could help resolve this aspect.

Regional vegetation inferred from the palynofloras of the YB

Table 2 lists cyst, spore and pollen taxa reported from the YB palynofloras. The ecological properties of their potential modern analogues are indicated and assigned to vegetation units (VU). Only very few taxa (e.g. Engelhardioideae p.p., Sapotaceae) are today restricted to lowland forests in warm temperate to tropical climates (VU 5a). Also *Carpinus*, *Ostrya* and *Tilia* are nowadays commonly found in lowland forests of temperate regions. The few lianas reported here may also have been part of lowland forests (both well-drained and swamp forests). The majority of tree species reported from the YB palynofloras grow in well-drained lowland and upland forests (VU 5b–7) and comprise both angiosperms and conifers. Among conifers, it is noteworthy that coal-forming taxodiaceous taxa are not well-represented suggesting that other plants contributed to the coal in the Yatağan Basin. In contrast, Pinaceae were fairly diverse. Although modern distributions of taxa such as *Cathaya*, *Cedrus* or *Picea* are typically confined to high elevations, the mass occurrence of *Cathaya* and *Cedrus* leafy shoots, cones and cone scales in late Miocene deposits of northern Greece (Velitzelos et al. 2014) suggests that these elements could also have grown at lower elevation.

Similar patterns of shifting of ecological niches are seen in ancestors of mountain goats (Solounias and Moelleken 1992). Among angiosperms, trees and shrubs include both deciduous and evergreen taxa and may have contributed to different types of forest vegetation. Fagaceae (*Fagus*, *Quercus* sect. *Cerris*, *Q.* sect. *Ilex*) most likely were the dominating forest elements in the surroundings of the YB.

Among herbaceous plants, a great number might have been associated with open lake shore vegetation including areas that temporarily fell dry. *Typha* and *Typha*-allies may have formed a reed belt in some places. Only few herbaceous taxa (e.g. the ferns *Pteris* and *Osmunda*) are characteristic elements of forests.

In summary, the regional vegetation as inferred from the extensive palynological record of the YB floras consisted of different forest types, including broadleaved thermophilous lowland forests, temperate lowland and upland forests as well as mixed broadleaved and conifer forests at mid and high elevations. In addition, rich riparian forests were present around the lake and rivers. Coal-forming swamp forests may have included taxodiaceous conifers and angiosperms such as *Myrica*, *Alnus* and *Decodon*. Open vegetation was restricted to disturbed and shore areas.

Attempting a standardised nomenclature for cysts, pollen and spores—comparing the palynomorphs of the YB to previously published literature

At present, no standardised correlation of palynomorphs from Turkish Neogene palynofloras exists. Such an attempt was made for the Neogene of Poland and resulted in four comprehensive pollen and spore atlases (Stuchlik et al. 2001, 2002, 2009, 2014).

Since the 1960s, many palynological studies focussed on Miocene deposits of western Anatolia (e.g. Nakoman 1967; Benda 1971; Ediger 1990; Gemici et al. 1990, 1991, 1993; Takahashi and Jux 1991; Akgün 1993; Akgün and Akyol 1999; Jiménez-Moreno 2005; Akgün et al. 2007; Kayseri 2010; Kayseri and Akgün 2010; Kayseri-Özer et al. 2014a, 2014b; Bozcu et al. 2015). Early studies used the abotanical, morphology-based nomenclature (see, e.g. Potonié 1931; Thomson and Pflug 1953) for fossil palynomorphs. Later studies increasingly used a botanical nomenclature to name palynomorphs. Regardless of which nomenclature was used, most studies indicated botanical affinities of the encountered palynomorphs.

In this and two previous studies (Bouchal et al. 2016, 2017), a combined LM and SEM approach was used to achieve best possible botanical determination for palynomorphs for three coeval sections in the YB. At the same time, it was noticed that in the published literature for the same fossil-taxon, a variety of botanical affinities had been indicated by different authors (S 2). Using the well-documented (LM and SEM) studies on YB lignite mine sections (this study;

Bouchal et al. 2016, 2017) as a taxonomical and morphological baseline, I compared 24 published accounts on (preferably figured) dispersed palynomorphs from early to middle Miocene deposits of western Anatolia. Although the palynological record of this time span and region likely is more diverse and complex than that of three sections of a single basin, a fairly high degree of homogeneity in composition (not in abundance) at regional scale has previously been noted by other authors (Benda 1971; Takahashi and Jux 1991; Akgün et al. 2007). In Table S 2, both botanical and abotanical taxa were compiled (i) to visualise the various palynological concepts used for this region since the 1960ies; (ii) to discriminate well-documented (common) taxa from those that so far lack documentation; and (iii) to narrow down the list of over 400 names that have been used in reviewed literature to the ca 170 taxa that are botanically (using LM and SEM) recognisable for the YB. The resulting redundancies of names are highly misleading when discussing past biodiversity but may also affect taxonomic interpretation and as such the inference of palaeoenvironments. Finally, (iv) they were compiled to provide a basis for further scientific discussion. In the following, I provide a few examples to illustrate why a standardised palynomorph nomenclature with updated botanical affinities will improve regional environmental comparisons and palaeoecological inference.

The name *Laevigatosporites haardti* is commonly used for psilate monolet spores. This stratigraphically widespread and rather featureless spore type is found in several extant fern families (e.g. Aspleniaceae, Davalliaceae, Dryopteridaceae, Gleicheniaceae, Lomariopsidaceae, Oleandraceae, Thelypteridaceae, Vittariaceae, Polypodiaceae; see Tyron and Lugardon 1991) but has mainly been associated with Polypodiaceae in the reviewed literature (S 2). If using this name, it should be clearly stated that the exact botanical affinities of this taxon cannot be established using spore morphology.

The former Taxodiaceae, “Taxodiaceae pollen”, commonly used as synonymous of papillate cupressaceous pollen, are currently included within the Cupressaceae and its former members have been assigned to the subfamilies Taiwanioidae, Athrotaxoidae, Sequoioidae and Taxodioidae (Earle 2010; Farjon 2005). Several studies demonstrated the limited taxonomic value of papillate and non-papillate Cupressaceae pollen (Kedves 1985; Bortenschlager 1990; Grimm et al. 2016). For identification to subfamily level, LM and SEM investigation of exceptionally well-preserved and complete fossil material (3D preservation) is needed (Grimsson and Zetter 2011); such type of preservation has not been reported for any of the reviewed pollen floras of western Anatolia. Since modern members of the Cupressaceae are ecologically very diverse, overly specific (to genus level) identifications run the risk of great error when inferring palaeoenvironments.

The botanical affinity of the fossil species *Pityopollenites libellus* (R.Potonié) Nakoman has been assumed to be with

the mainly southern hemispheric family Podocarpaceae or its genus *Podocarpus* (S 2). Under SEM, all YB specimens falling within the morphological range of this fossil-taxon show unequivocal characteristics (microechini) of the Pinaceae *Cathaya* (Bouchal et al. 2016, 2017). Thus, numerous reports of *Podocarpus* for the Neogene of western Anatolia would need to be verified or rejected by SEM investigations before any biogeographic or palaeoenvironmental conclusions can be drawn.

Tricolporopollenites megaexactus, a fossil species affiliated to Cyrillaceae, is commonly reported and figured in the reviewed literature (S 2). Combined LM and SEM investigation demonstrates that this fossil species shares morphological characteristics (size, shape, aperture) with pollen of the Lythraceae genus *Decodon*. A first, revised record of *Decodon* for Turkey shows a stratigraphic range, at least, from middle Miocene to early Pleistocene (this study; Bouchal et al. 2016, 2017; Alçiçek et al. 2017).

Likewise, dispersed pollen in Neogene western Anatolian strata has frequently been determined as *Castanea*, *Castanopsis* and/or *Lithocarpus* or assigned to the fossil species *Tricolporopollenites cingulum*, *T. cingulum oviformis* or *T. oviformis* for which affinities with *Castanopsis* and *Lithocarpus* were assumed. However, pollen of extant Castanoideae is strikingly uniform and not sufficiently distinct in LM and SEM to distinguish different genera of this polyphyletic group (see, e.g. Pragłowski 1984). Furthermore, poorly preserved pollen of an extinct Castanoideae, *Trigonobalanopsis*, is indistinguishable in LM from extant castanoids and can only be securely determined using SEM. *Trigonobalanopsis* is not uncommon in YB palynofloras and hence may be hidden behind some of the names mentioned above from other localities of western Anatolia. Hence, the great diversity of castanoid Fagaceae implied by the reviewed palynological literature is highly misleading. For the reviewed LM investigations, only the botanical affiliation Castanoideae gen. indet. ought to be used for such palynomorphs.

These are but a few examples out of many which illustrate the urgent need of a catalogue of palynomorphs from Neogene strata of western Anatolia, standardising nomenclature and taxonomic affinities and documenting cysts, spores and pollen using LM and SEM. The skills, knowledge, experience and archives of all palynologists currently working in this geographical region would need to be joined to achieve this task.

Acknowledgements Funding by the Swedish Research Council (VR) is acknowledged. Tuncay H. Güner, Istanbul, is thanked for accompanying me during fieldwork and the staff of the Salihpaşalar lignite mine for facilitating work in the mining area. Shirley Graham is acknowledged for sharing her expertise on Lythraceae pollen. Reinhard Zetter and Thomas Denk are thanked for sharing their highly valued palaeobotanical knowledge of this region and help with the manuscript. Fridgeir Grimsson and an anonymous reviewer provided constructive comments on the first version of the manuscript.

Compliance with ethical standards

Conflict of interest: The author declares that he has no conflict of interest.

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References

- Akgün, F. (1993). Palynological age revision of the Neogene Soma coal basin. *Bulletin of the Geological Society of Greece*, 28, 151–170.
- Akgün, F., & Akyol, E. (1999). Palynostratigraphy of the coal-bearing Neogene deposits in Büyük Menderes Graben, western Anatolia. *GEOBIOS*, 32(3), 367–383.
- Akgün, F., Kayseri, M. S., & Akkiraz, M. S. (2007). Palaeoclimatic evolution and vegetational changes during the Late Oligocene–Miocene period in western and central Anatolia (Turkey). *Palaeogeography, Palaeoclimatology, Palaeoecology*, 253, 56–90.
- Akkiraz, M. S. (2011). Vegetation and climate in the Miocene deposits of southern side of Büyük Menderes Graben, Şahinalı-2 core, SW Turkey. *Bulletin of Geosciences*, 86(4), 859–878.
- Akkiraz, M. S., Akgün, F., Utescher, T., Wilde, V., Bruch, A. A., Mosbrugger, V., et al. (2012). Palaeoflora and climate of lignite-bearing lower-middle Miocene sediments in the Seyitömer and Tunçbilek sub-basins, Kütahya Province, Northwest Turkey. *Turkish Journal of Earth Sciences*, 21, 213–235 Maden Tetkik Arama Dergisi, 11.
- Akyol, E., & Akgün, F. (1990). Bigadiç. Kestelek, Emet ve Kırka boratlı Neojen tortullarının palinolojisi ve karşılaştırılması. *Maden Tetkik ve Arama Dergisi*, 111, 165–173.
- Alçiçek, H. (2010). Stratigraphic correlation of the Neogene basins in southwestern Anatolia: regional palaeogeographical, palaeoclimatic and tectonic implications. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 291, 297–318.
- Alçiçek, H., Wesselingh, F. P., Alçiçek, M. C., Jiménez-Moreno, G., Feijen, F. J., van den Hoek Ostende, L. W., Mayda, S., & Tesakov, A. S. (2017). A multiproxy study of the early Pleistocene palaeoenvironmental and palaeoclimatic conditions of an anastomosed fluvial sequence from the Çameli Basin (SW Anatolia, Turkey). *Palaeogeography, Palaeoclimatology, Palaeoecology*, 467, 232–252.
- Atalay, Z. (1980). Muğla-Yatağan ve yakın dolaylı karasal Neojen'inin stratigrafi araştırması. *Bulletin of the Geological Society Turkey*, C23, 93–99.
- Barento, C., Candau, P., Díez, M. J., Fernández, I., Fernández Paniagua, I., Godoy, C., et al. (1987). *Atlas polínico de Andalucía occidental*. Sevilla: Instituto de desarrollo regional de la Universidad de Sevilla.
- Becker-Platen, J. D. (1970). Lithostratigraphische Untersuchungen im Känozoikum Südwest-Anatoliens (Türkei) (Känozoikum und Braunkohlender der Türkei, 2). *Beihefte zum Geologischen Jahrbuch*, 97, 1–244.
- Becker-Platen, J. D., Benda, L., & Steffens, F. (1977). Litho- und biostratigraphische Deutung radiometrischer Altersbestimmungen aus dem Jungtertiär der Türkei. *Geologisches Jahrbuch*, B25, 139–167.
- Benda, L. (1971). Grundzüge einer pollenanalytischen Gliederung des türkischen Jungtertiärs (Känozoikum und Braunkohlender der Türkei, 4). *Beihefte zum Geologischen Jahrbuch*, 113, 1–45.
- Beug, H. J. (2004). *Leitfaden der Pollenbestimmung für Mitteleuropa und angrenzende Gebiete*. München: Dr. Friedrich Pfeil.
- Blackmore, S. (1984). The Northwest European pollen flora, 32: Compositae-Lactuceae. *Review of Palaeobotany and Palynology*, 42(45–85), 45–85.
- Blackmore, S., Steinmann, J. A. J., Hoen, P. P., & Punt, W. (2003). The Northwest European pollen flora, 65: Betulaceae and Corylaceae. 123(71–98), 71.
- Bortenschlager, S. (1990). Aspects of pollen morphology in the Cupressaceae. *Grana*, 29(2), 129–137.
- Bouchal, J. M., Mayda, S., Grímsson, F., Akgün, F., Zetter, R., & Denk, T. (2017). Miocene palynofloras of the Tınaz lignite mine, Muğla, southwest Anatolia: taxonomy, palaeoecology and local vegetation change. *Review of Palaeobotany and Palynology*, 243, 1–36.
- Bouchal, J. M., Zetter, R., Grímsson, F., & Denk, T. (2016). The middle Miocene palynoflora and palaeoenvironments of Eskişehir (Yatağan Basin, southwestern Anatolia): a combined LM and SEM investigation. *Botanical Journal of the Linnéan Society*, 182(1), 14–79.
- Bozcu, M., Akgün, F., Grüdäl, G., Bozcu, A., Yeşilyurt, S. K., Karaca, Ö., et al. (2015). Evolution of Çan-Etili (Çanakkale - NW Turkey) lignite basin: sedimentology, petrology, palynology and lignite characterization. *International Journal of Sediment Research*, 30(3), 190–207.
- Cerceau-Larrivall, M. T., Straka, H., & Friedrich, B. (1984). Palynologia Madagassica et Mascarenica: Fam. 155–166. *Tropische und subtropische Pflanzenwelt*, 51, 595–638.
- Chen, S.-C., Zhao, X.-P., Ni, S.-F., Fu, C.-X., & Cameron, K. M. (2006). The systematic value of pollen morphology in Smilacaceae. *Plant Systematics and Evolution*, 259, 19–37.
- Christensen, P. B., & Blackmore, S. (1988). The northwest European pollen flora, 40: Tiliaceae. *Review of Palaeobotany and Palynology*, 57, 33–43.
- Clarke, G. C. S. (1978). Pollen morphology and generic relationships in the Valerianaceae. *Grana*, 17, 61–75.
- Clarke, G. C. S., & Jones, M. R. (1977). The northwest European pollen flora, 16: Valerianaceae. *Review of Palaeobotany and Palynology*, 24, 155–179.
- Clarke, G. C. S., Punt, W., & Hoen, P. P. (1991). The northwest European pollen flora, 51: Ranunculaceae. *Review of Palaeobotany and Palynology*, 69, 117–271.
- Denk, T. (2016). Palaeoecological interpretation of the late Miocene landscapes and vegetation of northern Greece: a comment to Merceron et al., 2016. *Geobios*, 49, 135–146.
- Denk, T., & Grimm, G. W. (2009). Significance of pollen characteristics for infrageneric classification and phylogeny in *Quercus* (Fagaceae). *International Journal of Plant Sciences*, 170(7), 926–940.
- Denk, T., Grimm, G. W., Manos P. S., Deng, M., & Hipp, A. (2017). An updated infrageneric classification of the oaks: review of previous taxonomic schemes and synthesis of evolutionary patterns. In E. Gil-Peregrin, J. J. Peguero-Pina & D. Sancho-Knapik (Eds.), *Oaks physiological ecology. Exploring the functional diversity of genus Quercus. Tree physiology*, 7. Springer Nature, Cham, Switzerland.
- Denk, T., Velitzelos, D., Güner, T. H., & Ferrufino-Acosta, L. (2015). *Smilax* (Smilacaceae) from the Miocene of western Eurasia with Caribbean biogeographic affinities. *American Journal of Botany*, 102(3), 423–438.
- Diethart, B. (2005). *Parietaria officinalis*. In: PalDat (2016-07-18)—a palynological database University of Vienna. Online publication. Accessed 29-11-2017. https://www.paldat.org/pub/Parietaria_officinalis/301233
- Donoghue, M. J. (1985). Pollen diversity and exine evolution in *Viburnum* and *Caprifoliaceae* sensu lato. *Journal of the Arnold Arboretum*, 66, 421–469.
- Earle, C. J. (2010). The gymnosperm database. Online publication. Accessed 29-11-2017. <http://www.conifers.org/>.

- Ediger, V. S. (1990). Paleopalynology of coal-bearing Miocene sedimentary rocks associated with volcanics of the Biga Peninsula (NW Turkey) and the effect of volcanism on vegetation. *Neues Jahrbuch der Geologie und Paläontologie, Abhandlungen*, 180(2), 259–277.
- Edwards, K. J. (1981). The separation of *Corylus* and *Myrica* pollen in modern and fossil samples. *Pollen et Spores*, 23(2), 205–218.
- El-Ghazaly, G., & Chaudhary, R. (1993). Pollen morphology of some species of the genus *Euphorbia* L. *Review of Palaeobotany and Palynology*, 78, 293–319.
- Erdei, B., Yavuz, N., Akgün, F., Hably, L., 2002. Some data to the Miocene flora of Western Turkey. *6th European Palaeobotany Palynology Conference Athens*, pp. 79–80.
- Erdtman, G. (1952). *Pollen morphology and plant taxonomy*. Stockholm: Almqvist & Wiksell.
- Erkül, F., Helvacı, C., & Sözbilir, H. (2005). Stratigraphy and geochronology of the Early Miocene volcanic units in the Bigadiç Borate Basin, Western Turkey. *Turkish Journal of Earth Science*, 14, 227–253.
- Ersoy, E. Y., Çemen, I., Helvacı, C., & Billor, M. Z. (2014). Tectono-stratigraphy of the Neogene basins in Western Turkey: implications for tectonic evolution of the Aegean Extended Region. *Tectonophysics*, 635, 33–58.
- Farjon, A. (2005). A monograph of Cupressaceae and Sciadopitys. Kew: Kew Royal Botanic Gardens.
- Gemici, Y., & Akgün, F. (1992). Macro and micro fossil flora of the Akçaşehir (Tire-Izmir) Neogene basin. *Turkish Journal of Botany*, 16, 383–393.
- Gemici, Y., Akyol, E., & Akgün, F. (1993). Şahınlı (Aydın) Neojen havzasının fosil makro ve mikorflorası. *Doğa. Turkish Journal of Botany*, 17, 91–106.
- Gemici, Y., Akyol, E., Akgün, F., & Seçmen, Ö. (1991). Soma kömür havzası fosil makro ve mikorflorası. *Maden Teknik ve Arama Dergisi*, 112, 161–178.
- Gemici, Y., Akyol, E., Seçmen, Ö., & Akgün, F. (1990). Macro et microflore fossile du Bassin Néogène d'Eskihisar (Yatağan-Muğla). *Journal of the Faculty of Science Ege University, series B*, 12, 29–41.
- Graham, A., Nowicke, J. W., Skvarla, J. J., Graham, S. A., Patel, V., & Lee, S. (1985). Palynology and systematics of the Lythraceae. I. Introduction and genera *Adenaria* through *Ginoria*. *American Journal of Botany*, 72(7), 1012–1031.
- Graham, A., Nowicke, J. W., Skvarla, J. J., Graham, S. A., Patel, V., & Lee, S. (1987). Palynology and systematics of the Lythraceae. II. Genera *Haitia* through *Peplis*. *American Journal of Botany*, 74(6), 829–850.
- Graham, S. A., Diazgranados, M., & Barber, J. C. (2011). Relationships among the confounding genera *Ammanium*, *Hionanthera*, *Nesaea* and *Rotala* (Lythraceae). *Botanical Journal of the Linnéan Society*, 166, 1–19.
- Graham, S. A., Hall, J. C., Sytsma, K. J., & Shi, S.-h. (2005). Phylogenetic analysis of the Lythraceae based on four gene regions and morphology. *International Journal of Plant Sciences*, 166(6), 995–1017.
- Grimm, G. W., Bouchal, J. M., Denk, T., & Potts, A. J. (2016). Fables and foibles: a critical analysis of the Palaeoflora database and the Coexistence Approach for palaeoclimate reconstruction. *Review of Palaeobotany and Palynology*, 233, 216–235. <https://doi.org/10.1016/j.revpalbo.2016.07.001>.
- Grimsson, F., Denk, T., & Zetter, R. (2008). Pollen, fruits, and leaves of *Tetracentron* (Trochodendraceae) from the Cainozoic of Iceland and western North America and their palaeobiogeographic implications. *Grana*, 47, 1–14.
- Grimsson, F., Ferguson, D. K., & Zetter, R. (2012). Morphological trends in the fossil pollen of *Decodon* and the palaeobiogeographic history of the genus. *International Journal of Plant Sciences*, 173, 1–22.
- Grimsson, F., Grimm, G. W., Meller, B., Bouchal, J. M., & Zetter, R. (2016). Combined LM and SEM study of the middle Miocene (Sarmatian) palynoflora from the Lavanttal Basin, Austria: Part IV. Magnoliophyta 2—Fagales to Rosales. *Grana*, 55(2), 101–163.
- Grimsson, F., & Zetter, R. (2011). Combined LM and SEM study of the middle Miocene (Sarmatian) palynoflora from the Lavanttal Basin, Austria: part II. Pinophyta (Cupressaceae, Pinaceae and Sciadopityaceae). *Grana*, 50(4), 262–310.
- Güner, H. T. (2016). The Miocene floras and vegetation of the Yatağan Basin, western Anatolia. Unpublished PhD thesis, Istanbul University, Istanbul.
- Güner, H. T., Bouchal, J. M., Köse, N., Göktas, F., Mayda, S., & Denk, T. (2017). Landscape heterogeneity in the Yatağan Basin (southwestern Turkey) during the middle Miocene inferred from plant macrofossils. *Palaeontographica, Abteilung B*, 296(1–6), 113–171.
- Guo, S., Fujiki, T., & Miyoshi, N. (1994). Pollen morphology by means of scanning electron microscope: 13. Oleaceae (Angiospermae). *Japanese Journal of Palynology*, 40(2), 99–112.
- Halbritter, H. (2015). *Parietaria judaica*. In: PalDat (2015-04-15)—a palynological database. Online publication. Accessed 29-11-2017. https://www.paldat.org/pub/Parietaria_judaica/300062
- Halbritter, H., Hesse, M., & Weber, M. (2012). The unique design of pollen tetrads in *Dionaea* and *Drosera*. *Grana*, 51(2), 148–157.
- Harley, M. M. (1991). The pollen morphology of the Sapotaceae. *Kew Bulletin*, 46(3), 379–491.
- Hawksworth, F. J. m., & Wiens, D. (1972). Biology and classification of dwarf mistletoes (*Arceuthobium*). *Agriculture Handbook*, 401, 228.
- Hebda, R. J., & Chinnappa, C. C. (1990). Studies on pollen morphology of Rosaceae in Canada. *Review of Palaeobotany and Palynology*, 64, 103–108.
- Hebda, R. J., & Chinnappa, C. C. (1994). Studies on pollen morphology of Rosaceae. *Acta Botanica Gallica*, 141(2), 183–193.
- Hebda, R. J., Chinnappa, C. C., & Smith, B. M. (1988a). Pollen morphology of the Rosaceae of Western Canada. I. Agrimonia to Crataegus. *Grana*, 27, 95–113.
- Hebda, R. J., Chinnappa, C. C., & Smith, B. M. (1988b). Pollen morphology of the Rosaceae of Western Canada II. Dryas, Fragaria, Holodiscus. *Canadian Journal of Botany*, 66, 595–612.
- Hesse, R. W., Halbritter, H., Zetter, R., Weber, M., Frosch-Radivo, A., & Ulrich, S. (2009). *Pollenterminology—an illustrated handbook*. Wien, New York: Springer.
- Hinsbergen, D. J. J van & Schmid, S. M. (2012). Map view restoration of Aegean–West Anatolian accretion and extension since the Eocene. *Tectonics*, 31, TC5005 1–40.
- Hofmann, C. C., Zetter, R., & Draxler, I. (2002). Pollen- und Sporenvergesellschaftungen aus dem Karpatium des Korneuburger Beckens (Niederösterreich). *Beiträge zur Paläontologie*, 27, 17–43.
- Inaner, H., Nakoman, E., & Karayigit, A. I. (2008). Coal resource estimation in the Bayir field, Yatağan-Muğla, SW Turkey. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, 30, 1005–1015.
- Jiménez-Moreno, G. (2005). *Utilización del análisis polínico para la reconstrucción de la vegetación, clima y estimación de paleoaltitudes a lo largo de arco alpino europeo durante el Mioceno (21–8 Ma)*. Granada: Granada.
- Jones, C. A., & Blackmore, S. (1988). The northwest European pollen Flora, 38: Lycopodiaceae. *Review of Palaeobotany and Palynology*, 57, 1–25.
- Jones, G. D., Bryant, V. M. J., Hoag Lieux, M., Jones, S. D., & Lingren, P. D. (1995). *Pollen of the southeastern United States: with emphasis on melissopalynology and entomopalynology* (Vol. 30, AASP Contribution Series).
- Kasaplıgil, B. (1977). Tertiary conifer-hardwood forest from the vicinity of Güvem village, near Kizilcahamam, Ankara. *Bulletin of the mineral research and exploration institute of Turkey*, 88, 25–55.

- Kayseri, M. S. (2010). Oligo-Miocene palynology, palaeobotany, vertebrate, marine faunas, palaeoclimatology and palaeovegetation of the Oren Basin (north of the Gökova Gulf), western Anatolia. PhD Thesis, Dokuz Eylül University, Izmir. 1–552.
- Kayseri, M. S., & Akgün, F. (2010). The late Burdigalian–Langhian time interval in Turkey and the palaeoenvironment and palaeoclimatic implications and correlation of Europe and Turkey: late Burdigalian–Langhian palynofloras and palaeoclimatic properties of the Muğla–Milas (Kultak). *Geological Bulletin of Turkey*, 53(1), 1–44.
- Kayseri-Özer, M. S., Akgün, F., Mayda, S., & Kaya, T. (2014a). Palynofloras and vertebrates from Muğla–Ören region (SW Turkey) and palaeoclimate of the Middle Burdigalian–Langhian period in Turkey. *Bulletin of Geosciences*, 89(1), 137–162.
- Kayseri-Özer, M. S., Sözbilir, H., & Akgün, F. (2014b). Miocene palynoflora of the Kocaçay and Cumaovasi basins: a contribution to the synthesis of Miocene palynology, palaeovegetation in western Turkey. *Turkish Journal of Earth Sciences*, 23, 233–259.
- Kedves, M. (1985). LM, TEM and SEM investigations on recent inaperturate Gymnospermatophyta pollen grains. *Acta Biologica Szegedinesnsis*, 31, 129–146.
- Koç, Ç. S. (2017). Palaeoflora and palaeoclimate of the coal bearing sediments in the Tınaz (Muğla–Yatağan) and surround. Unpublished Master's Thesis, Ege University, Izmir.
- Köhler, E., & Elsbeth, L. (1979). A contribution to distinguishing cereal from wild grass pollen grains by LM and SEM. *Grana*, 18, 133–140.
- Knobloch, E., & Kvaček, Z. (1965). *Byttneriophyllum tiliaefolium* (Al.Braun) Knobloch Kvaček in den tertiären Floren der Nordhalbkugel. *Sborník geologických věd Paleontologie*, 5, 123–166.
- Krutzsch, W. (1963). *Atlas der mittel- und jungtertiären dispersen Sporen- und Pollen- sowie der Mikroplanktonformen des nördlichen Mitteleuropas II*. Berlin: Deutscher Verlag der Wissenschaft.
- Krutzsch, W., & Pacltová, B. (1990). Die Phytoplankton-Mikroflora aus den Pliozänen Süßwasserablagerungen des Cheb-Beckens (Westböhmen, CSFR). *Acta Universitatis Carolinae - Geologica*, 34(4), 345–420.
- Kvavadze, E. V. (1988). *The pollen of Taxodiaceae and its peculiarities*. Tbilisi: Metsniereba.
- Li, T. Q., Cao, H. J., Kang, M. S., Zhang, Z. X., Zhao, N., & Zhang, H. (2010). *Pollen flora of China woody plants by SEM*. Beijing: Science Press.
- Maciejewska, I. (1997). Pollen morphology of the Polish species of the family Caprifoliaceae, part 2. *Acta Societatis Botanicorum Poloniae*, 66(2), 143–151.
- Manchester, S. R. (1989). Attached reproductive and vegetative remains of the extinct American-European genus *Cedrelospermum* (Ulmaceae) from the Early Tertiary of Utah and Colorado. *American Journal of Botany*, 76, 256–276.
- Mädler, K., & Steffens, P. (1979). Neue Blattfloren aus dem Oligozän, Neogen und Pleistozän der Türkei (Känozoikum und Braunkohlen der Türkei. 20.). *Geologisches Jahrbuch*, B33, 3–33.
- Miyoshi, N., Fujiki, T., & Kimura, H. (2011). *Pollenflora of Japan*. Sapporo: Hokkaido: University Press.
- Nakoman, E. (1967). Microflore des dépôts tertiaires du sud-ouest de l'Anatolie. *Pollen et Spores*, 9(1), 121–142.
- Neubauer, T. A., Harzhauser, M., Kroh, A., Georgopoulou, E., & Mandic, O. (2015). A gastropod-based biogeographic scheme for the European Neogene freshwater systems. *Earth-Science Reviews*, 143, 98–116.
- Nilsson, S. (1988). A survey of the pollen morphology of *Olea* with particular reference to *Olea europaea sens. lat.* *Kew Bulletin*, 43(2), 303–315.
- Page, J. S. (1978). A scanning electron microscope survey of grass pollen. *Kew Bulletin*, 32(2), 313–319.
- Paicheler, J.-C., & Blanc, C. (1981). La flore du bassin lacustre miocène de Bes-Konak (Anatolie septentrionale, Turquie). *Géologie Méditerranéenne*, 8, 19–60.
- Pennington, T. D. (2004). Sapotaceae. In K. Kubitzki (Ed.), *The families and genera of vascular plants 6—flowering plants—Dicotyledons—Celastrales, Oxalidales, Rosales, Comales, Ericales* (Vol. 6, pp. 390–421). Berlin: Springer-Verlag.
- Perveen, A., Grafström, E., & El-Ghazaly, G. (2004). World pollen and spore flora 23. Malvaceae Adams. p.p.-subfamilies: Grewioideae, Tilioideae, Brownlowioideae. *Grana*, 43, 129–155.
- Popov, S. V., Rögl, F., Rozanov, A. Y., Steininger, F. F., Shcherba, I. G., & Kovac, M. (2004). Lithological-Paleogeographic maps of Paratethys. 10 maps. Late Eocene to Pliocene. *Courier Forschungsinstitut Senckenberg*, 250, 1–46.
- Potonié, R. (1931). Zur Mikroskopie der Braunkohlen. Tertiäre Sporen- und Blütenstaubformen (Vierte Mitteilung). *Zeitschrift für Gewinnung und Verwertung der Braunkohle*, 30(27), 554–556.
- Pragłowski, J. (1984). Fagaceae Dumort.-Castaneae Oerst. In S. Nilsson (Ed.), *World pollen and spore Flora* (Vol. 13). Stockholm: The Almquist & Wiksell Periodical Company.
- Punt, W. (1984). The northwest European pollen flora, 37: Umbelliferae. *Review of Palaeobotany and Palynology*, 42, 155–364.
- Punt, W., Bos, J. A. A., & Hoen, P. P. (1991). The northwest European pollen flora, 45: Oleaceae. *Review of Palaeobotany and Palynology*, 69, 23–47.
- Punt, W., & Hoen, P. P. (2009). The northwest European pollen flora, 70: Asteraceae-Asterioideae. *Review of Palaeobotany and Palynology*, 157, 22–183.
- Punt, W., Hoen, P. P., Blackmore, S., Nilsson, R. H., & Le Thomas, A. (2007). Glossary of pollen and spore terminology. *Review of Palaeobotany and Palynology*, 143, 1–81.
- Punt, W., & Malotau, M. (1984). The northwest European pollen flora, 31: Cannabaceae, Moraceae and Urticaceae. *Review of Palaeobotany and Palynology*, 42, 23–44.
- Punt, W., Marks, A., & Hoen, P. P. (2003). The northwest European pollen flora, 60: Droseraceae. *Review of Palaeobotany and Palynology*, 123, 27–40.
- Purvis, M., Robertson, A., & Pringle, M. (2005). 40Ar–39Ar dating of biotite and sanidine in tuffaceous sediments and related intrusive rocks: implications for the early Miocene evolution of the Gördes and Selendi basins, W Turkey. *Geodinamica Acta*, 18, 239–253.
- Renault-Miskovsky, J., Girard, M., & Trouin, M. (1976). Observations de quelques pollen d'Oléacées au microscope électronique à balayage. *Bulletin de l'Association française pour l'Etude du Quaternaire*, 13(2), 71–86.
- Rögl, F. (1999). Mediterranean and Paratethys. facts and hypotheses of an Oligocene to Miocene paleogeography (short overview). *Geologica Carpathica*, 50, 339–349.
- Sachse, M. (2001). Oleaceous laurophyllous leaf fossils and pollen from European tertiary. *Review of Palaeobotany and Palynology*, 115, 213–234.
- Saraç, G. (2003). Türkiye Omurgalı Fossil Yatakları. *Scientific Report No. 10609*. Ankara: General Directorate of the Mineral Research and Exploration of Turkey.
- Sickenberg, O. (1975). Die Gliederung des höheren Jungtertiärs und Altquartärs in der Türkei nach Vertebraten und ihre Bedeutung für die internationale Neogen-Stratigraphie (Känozoikum und Braunkohlen der Türkei. 17.). *Geologisches Jahrbuch*, B15, 1–167.
- Sivak, J. (1978). Obsevation nouvelles sur les grains de pollen de *Tsuga*. *Pollen et Spores*, 15, 397–457.
- Solounias, N., & Moelleken, S. M. C. (1992). Dietary adaptations of two goat ancestors and evolutionary considerations. *Geobios*, 25, 797–809.

- Southworth, D. (1988). Isolation of exines from gymnosperm pollen. *American Journal of Botany*, 75(1), 15–21.
- Stafford, P. J. (1991). The northwest European pollen flora, 44: Selaginellaceae. *Review of Palaeobotany and Palynology*, 69, 1–22.
- Stafford, P. J. (1995). The northwest European pollen flora, 52: Marsileaceae. *Review of Palaeobotany and Palynology*, 88, 3–24.
- Stuchlik, L., Ziemińska-Tworzydło, M., Kohlman-Adamska, A., Grabowska, I., Słodkowska, B., Ważyńska, H., et al. (2009). *Atlas of pollen and spores of the Polish Neogene. Volume 3—angiosperms (1)* (Vol. Vol 3). Kraków: W. Szafer Institute of Botany, Polish Academy of Science.
- Stuchlik, L., Ziemińska-Tworzydło, M., Kohlman-Adamska, A., Grabowska, I., Słodkowska, B., Worobiec, E., et al. (2014). *Atlas of pollen and spores of the Polish Neogene. Volume 4—angiosperms (2)* (Vol. 4). Kraków: W. Szafer Institute of Botany, Polish Academy of Science.
- Stuchlik, L., Ziemińska-Tworzydło, M., Kohlman-Adamska, A., Grabowska, I., Ważyńska, H., & Sadowska, A. (2001). *Atlas of pollen and spores of the Polish Neogene. Volume 1—spores (Vol. 1)*. Kraków: W. Szafer Institute of Botany, Polish Academy of Science.
- Stuchlik, L., Ziemińska-Tworzydło, M., Kohlman-Adamska, A., Grabowska, I., Ważyńska, H., & Sadowska, A. (2002). *Atlas of pollen and spores of the Polish Neogene. Volume 2—gymnosperms. (Vol. 2)*. Kraków: W. Szafer Institute of Botany, Polish Academy of Science.
- Swenson, U., & Anderberg, A. A. (2005). Phylogeny, character evolution, and classification of Sapotaceae (Ericales). *Cladistics*, 21, 101–130.
- Takahashi, K., & Jux, U. (1991). Miocene palynomorphs from lignites of the Soma Basin (West Anatolia, Turkey). *Bulletin of the Faculty of Liberal Arts Nagasaki University (Natural Science)*, 32, 7–165.
- The NOW Community (2018). New and old worlds database of fossil mammals (NOW). Licensed under CC BY 4.0 Release 2008, Accessed 28–05-2018. Published on the Internet. <http://www.helsinki.fi/science/now/>
- Thiele-Pfeiffer, H. (1980). The Miocene microflora from the brown coal open-cast Oder mine near Wackersdorf/Oberpfalz. *Palaeontographica, Abteilung B*, 174(4–6), 95–224.
- Thomson, P. W., & Pflug, H. (1953). Pollen und Sporen des mitteleuropäischen Tertiärs. *Palaeontographica, Abteilung B*, 94(1–4), 1–138.
- Tyron, A. F., & Lugardon, B. (1991). *Spores of the Pteridophyta*. New York, Berlin, Heidelberg, London, Paris, Tokyo, Hong Kong, Barcelona: Springer.
- Van Campo-Duplan, M. (1951). Recherches sur la phylogénie des Taxodiaceae d'après leurs grains de pollen. *Travaux du Laboratoire Forestier de Toulouse, Tome II*, 4, 1–14.
- Van Campo-Duplan, M. (1953). Recherches sur la phylogénie des Cupressaceae d'après leurs grain de pollen. *Travaux du Laboratoire Forestier de Toulouse, Tome II*, 4, 1–20.
- Van Leeuwen, P., Punt, W., & Hoen, P. P. (1988). The northwest European pollen flora, 43: Polygonaceae. *Review of Palaeobotany and Palynology*, 57, 81–151.
- Velitzelos, D., Bouchal, J. M., & Denk, T. (2014). Review of the Cenozoic floras and vegetation of Greece. *Review of Palaeobotany and Palynology*, 204, 56–117. <https://doi.org/10.1016/j.revpalbo.2014.02.006>.
- Wang, Q., Dilcher, D. L., & Lott, T. A. (2007). *Podocarpium* A. Braun ex Sitzenberger 1851 from the middle Miocene of Eastern China and its palaeoecology and biogeography. *Acta Palaeobotanica*, 47, 237–251.
- Wen, J., & Nowicke, J. W. (1999). Pollen ultrastructure of *Panax* (the ginseng genus, Araliaceae), an eastern Asian and eastern North American dijunct genus. *American Journal of Botany*, 86(11), 1624–1636.
- Wessels, W. (2009). Miocene rodent evolution and migration—Muroidea from Pakistan, Turkey and Northern Africa. *Geologica Ultraiectina*, 307, 1–290.
- Wilce, J. H. (1972). Lycopod spores, I. General spore patterns and the generic segregates of *Lycopodium*. *American Fern Journal*, 62(3), 65–79.
- Worobiec, E. (2014). Fossil zygospores of Zygnemataceae and other microremains of freshwater algae from two Miocene palaeosinkholes in the Opole region, SW Poland. *Acta Palaeobotanica*, 54(1), 113–157.
- Worobiec, G., Worobiec, E., & Kvaček, Z. (2010). Neogene leaf Morphotaxa sl. in Europe. *International Journal of Plant Sciences*, 171(8), 892–914.
- Yavuz-İşık, N. (2007). Pollen analysis of coal-bearing Miocene sedimentary rocks from the Seyitömer Basin (Kütahya), Western Anatolia. *Geobios*, 40, 701–708.
- Yavuz-İşık, N., Saraç, G., Ünay, E., & Bruijn, H. de (2011). Palynological analysis of Neogene mammal sites of Turkey—vegetational and climatic implications. *Yerbilimeri*, 32(2), 105–120.
- Zetter, R. (1989). Methodik und Bedeutung einer routinemäßigen kombinierten lichtmikroskopischen und rasterelektronenmikroskopischen Untersuchung fossiler Mikroflora. *Courier Forschungsinstitut Senckenberg*, 109, 41–50.
- Zhang, Y.-L., & Chen, Y.-S. (1984). Studies on pollen morphology in Tiliaceae of China. *Acta Phytotaxonomica Sinica*, 22, 367–377.