PALAEOCLIMATIC AND PALAEOENVIRONMENTAL INTERPRETATION ON THE SARMATIAN DEPOSITS OF ŞUPANU FORMATION FROM COMĂNEŞTI BASIN (BACĂU COUNTY)

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Abstract. This paper describes and interpretes a Sarmatian palaeoflora identified within Şupanu Formation. This formation was intercepted in 2 outcrops: one located in Asău cuvette and the other one in Lăloaia-Galeon cuvette. Based on palaeofloristic investigations a palaeoenvironmental and palaeoclimatical reconstruction was accomplished. In the Sarmatian, Comăneşti Basin recorded an abundant plants biomass development, in a swamp environment, allowing coal layer formation. The **TAXODIACEAE** have been the main source in coal formation, plus some taxa such as *Typha* and *Phragmites*. Additionaly, was also identified a lowland riparian vegetation and other taxas from a mixed mesophytic forest. Palaeoclimatical values were estimated by the "Coexistence approach" method. This paper present also palynofacies analysis on basis of the organic matter extracted from analyzed samples. It was observed that organic matter is almost entirely derived from the continent (black coal phytoclasts, brown and yellow residues, woody tissues, spores and pollen).

Keywords: Sarmatian, palynoflora, palaeoclimat, palynofacies, Comăneşti Basin.

INTRODUCTION

Comăneşti Basin is located nearby Eastern Romanian Carpathians, on the middle course of Trotuş River (Fig. 1). The studied sedimentary basin represented a subsidence area with a molasse character during the Sarmatian and Maeotian. Because of different subsidence speeds within the basin, this was divided into several, north-south oriented cuvettes (Popescu-Voiteşti and Protopopescu, 1923; Băncilă, 1958; Micu et al., 1985). These cuvettes, from west to east, are: Lapoş, Asău, Lăloaia-Galeon, Sălătruc, Leorda-Văsieşti-Dărmăneşti, Larga and Taşbuga. Sarmatian and Maeotian deposits from Comăneşti Basin are discordantly- and transgressively-disposed over the External Carpathian Flysch (Tarcău and Vrancea Nappes) (Fig. 1) (Grasu et al., 2004). Regarding deposits' stratigraphy, Micu et al. (1985) separated three formations: Dofteana Formation, Şupanu Formation and Dărmăneşti Formation.

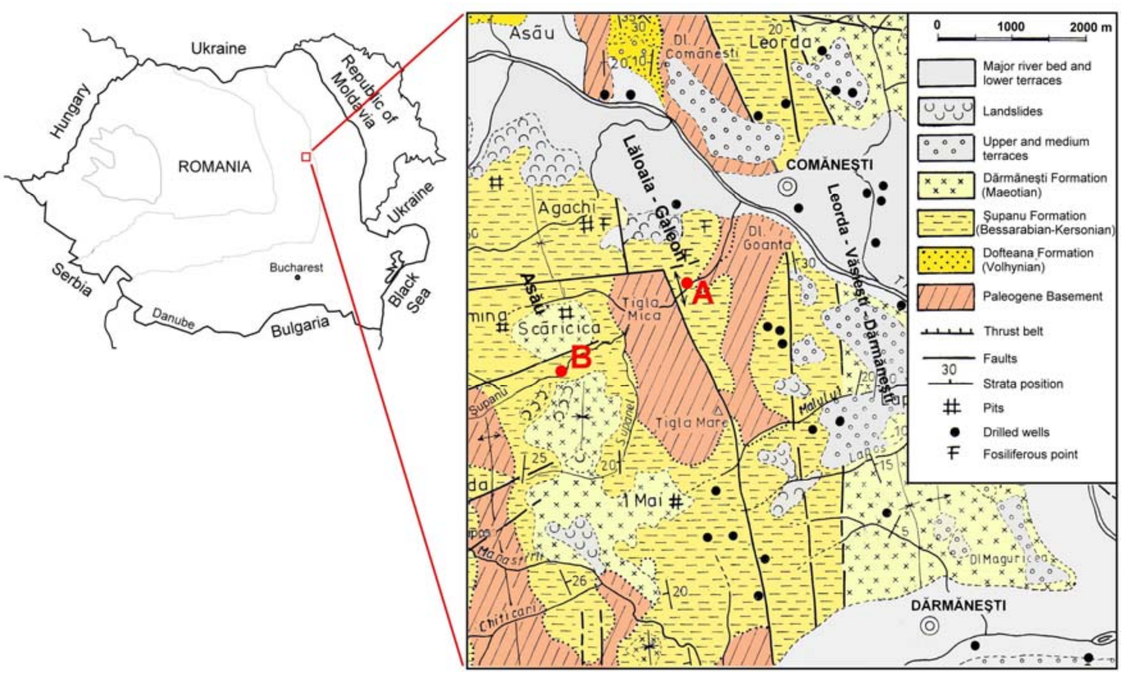

Fig. 1 Geological map of the Comăneşti Basin (after Nicolaescu et al., 1984; Micu et al., 1985, 1990).

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Dofteana Formation

This represents the oldest formation in the basin; it discordantly overlays the basment. According to different authors, the tickness is variable: 10–250 m (Băncilă, 1958), approximatively 250 m (Mutihac and Ionesi, 1974), 0–200 m (Micu et al., 1985) or up to 600 m (Nicolaescu et al., 1984).

Petrographically, this formation consists of conglomerates alongside with sandstones and pelites (Micu et al., 1985; Grasu et al., 2004).

Sedimentological research regarding Dofteana Formation was accomplished by Grasu et al. (2004). According to the authors, this formation was accumulated in a fan delta, which has prograded ino a marine basin dominated by waves. Based on the identification of a limestone with *Globigerina* intercalation in the lower part of the formation, cropping out along Larga valley (south-east Comăneşti Basin), the authors concluded that the sediments accumulated at a greater distance from shore. This may be an argument in the favour of the comunication between Comăneşti Basin and Eastern Carpathian foreland.

The age of the Dofteana Formation is very difficult to estimate because of the poor fossiliferous content. However, Lubenescu et al. (1986) identified a palynological assemblage where *Microtythodiscus* gender points to a Volhynian age. The same age was assumed by Grasu et al. (2004) based on stratigraphic arguments (the presence of Volhynian deposits nearby Comăneşti Basin, at Viişoara-Brăteşti).

Şupanu Formation

This formation is known as the „productive formation" because of the coal content. According to Micu et al. (1985), the thickness of the formation is variable in Asău and Lapoş cuvettes, being 300 m in the middle part of Leorda-Văsieşti-Dărmăneşti cuvette.

Petrographically, this formation consists of clays, silty-clays, wakes, sandstones, sands and coal intercalations. These coal intercalations can be found in all the cuvettes, but, only the coal layers from Asău cuvette bear economic importance (Givulescu, 1996). The most important layers are (thickness in brackets): Wagner (0.35–1.5 m), Agachi (0.35–1.35 m), Coroban (0.3–0.75 m) a.o. The author separates two types of peat bog for Comăneşti Basin: 1. costal peat bog, developed in larger cuvettes (Leorda-Văsieşti-Dărmăneşti cuvette); here coal is found only on the cuvette flanks, passing to the center into carboniferous clays and black shale; 2. central peat bog, characteristic for small cuvettes (Lapoş, Lăloaia-Galeon) where coal is thicker in the centre and thinner on flanks. Regarding coal genesis process, Givulescu (1996) has shown the importance of gender *Glyptostrobus* and *Taxodium,* plus hardwoods that have a predominant role in plant biomass accumulation. Micu et al. (1985) suggested that the plant biomass was autochthonous, consisting of a swamp assemblage; the subsidence control was the factor that favored the accumulation and preservation.

Compared with Dofteana Formation, the Şupanu Formation has more conclusive paleontological content; mammalian fauna, mollusks, foraminifera, fossil leaves and palynomorphs formed the basis of the biostratigraphical assessments. Mammalian fauna, according to Alexandrescu and Rădulescu (1994), consists of *Aceratherium incisivum* KAUP., *Hipparion* cf. *sarmaticum* LUNGU and *Dicerorhinus* cf. *orientalis* (SCHLOSSER) which indicate a Bessarabian age. The mollusks fauna consists of a small number of taxa including congerias, unionidae, mactras (*Sarmatimactra caspia* Eichw., *S.* cf. *crassicolis* Sinz. and *S.* cf. *alata* Mac.) giving an Upper Bessarabian–Kersonian age (Micu et al. 1985).

Macroflora identified in this formation was presented by Barbu (1934), Ciocârdel (1943), Givulescu (1957, 1963, 1968) and Micu et al. (1985), who cited species such as: *Glyptostrobus europaeus, Taxodium dubium, Osmunda parschlungiana, Betula prisca, Carpinus grandis, Fagus attenuata, Typha latissima* a.o.

Palynological assemblages were mentioned by Nicolaescu et al. (1984), Lubenescu et al. (1986) and Horaicu (1989). Main taxa cited were: *Betulaepollenites betuloides, Carpinuspollenites carpinoides minor, Microtytthodiscus clarus clarus, Neogenisporis neogenicus, Laevigatosporites haardti* a.o.

In this study we performed a paleofloristic investigation on Şupanu Formation, identified in two outcrops: the first one located in Lăloaia-Galeon cuvette, in the perimeter of the former quarry on Şupanu Valley (outcrop A; Fig. 1) and the second in Asău cuvette, upstream from the previous outcrop, along the same watercourse (outcrop B).

Dărmăneşti Formation

This youngest formation is overlaying Şupanu Formation (Micu et al., 1985). The thickness in Leorda-Văsieşti-Dărmăneşti cuvette is of approximately 380 m (Nicolaescu et al., 1984) or 200 m according to Chiriac (1959); in Asău cuvette it is 100 m (Micu et al., 1985).

According to Mutihac, Ionesi (1974) and Micu et al. (1985), this formation consists of cineritic sandstones and andesitic tuffs.

The paleontological content of Şupanu Formation is poor, only a few species of mollusks (*Anodonta maeotica, Unio moldavicum, Planorbis* div. sp., *Helix coqnardiana*), ostracods and palynomorphs (*Neogenisporites neogenicus, Betulaepollenites betuloides, Myricipites* sp.) being cited (Nicolaescu et al. 1984).

The biostratigraphic assessment of the formation was accomplished by Lubenescu et al. (1986). The authors identified a palynological assemblage of Maeotian age containing species of *Leiosphaeridia* and fresh or weakley-brackish waters species such as *Phtanoperidinium mucronatum*. This association differs from that found in Kersonian subjacent deposits,

STUDIED AREA. METHODS AND MATERIALS

The studied outcrops are located on Şupanu Valley, a right tributary of the Trotuş River (Fig. 1). The geographical coordinates of the outcrops are:

- Outcrop A: N 46° 24′ 28.2″. E 26° 25′ 26.0″. Alt. 425–465 m

The intercepted deposits from this outcrop belong to Şupanu Formation, belonging to Lăloaia-Galeon cuvette. The beds form a syncline (Fig. 2) consisting of a succession of grey clays, carbonaceous clays, sands and poorly-cemented sandstones with coal intercalations (coal tickness between 5–15 cm).

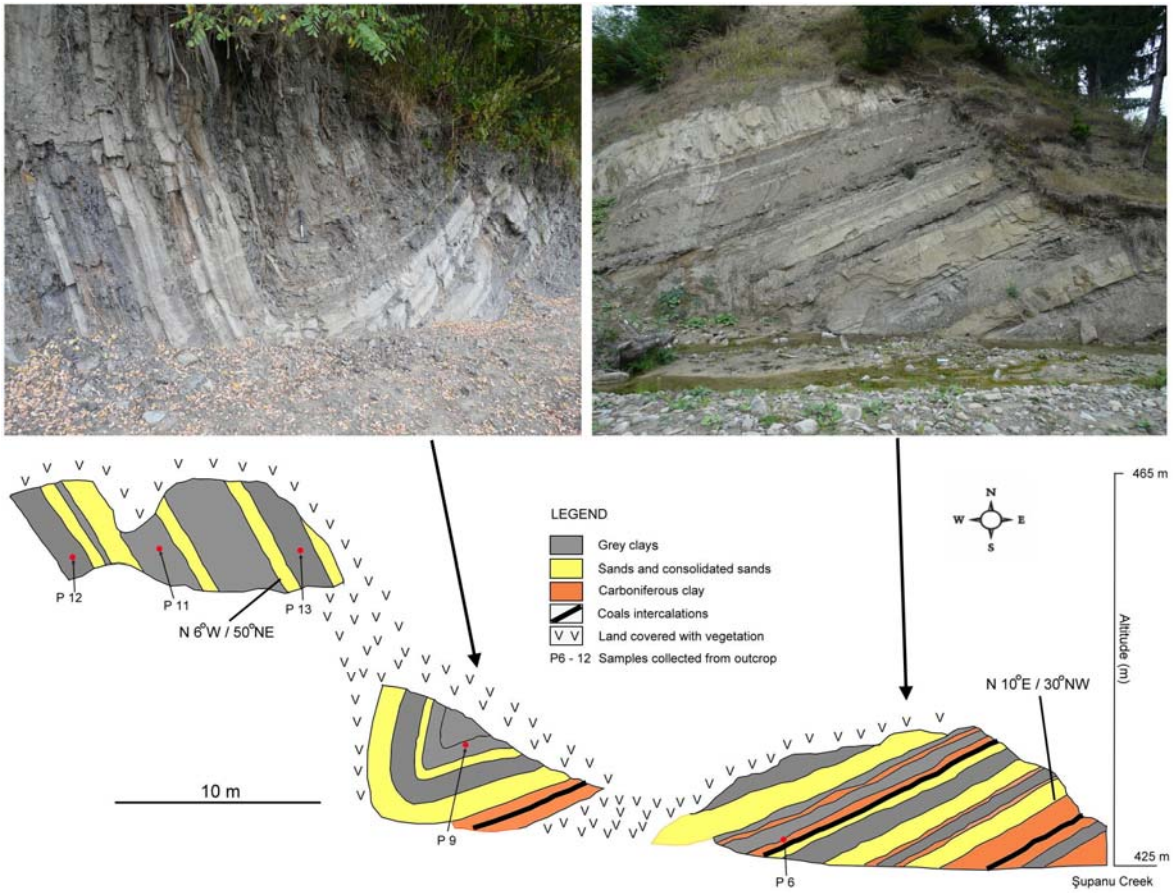

Fig. 2 Geological cross section through Şupanu Formation, on the western flank of the Lăloaia-Galeon cuvette (Şupanu Valley quarry, outcrop A, Fig. 1).

Five palynological samples have been collected from grey clays and carbonaceous clays (Fig. 2). Macroflora samples have been collected from the same place (the western part of the syncline).

- Outcrop B: N 46° 23′ 56.9″. E 26° 24′ 12.1″. Alt. 509–515 m

This outcrop is located upstream from the previous outcrop, on the Şupanu Valley. Stratigraphically, the deposits belong of Şupanu Formation (Asău cuvette), they are horizontally-disposed and consist in the lower part of sands with sandstone intercalations, and of grey clays and sandy clays in the upper part (Fig. 3). Two palynological samples have been collected from this outcrop (P20, P21).

The amount of sediments used for analysis was approximately 50 g for each sample. The samples have been treated with HCl (37 %) to remove the carbonate and afterward with HF (48 %) to remove the silicate minerals. The separation of palynomorphs from the resulted residue was achieved by centrifugation, using $ZnCl_2$, with 2.00 g/cm^3 density, as heavy liquid. The resulted organic fraction was inserted in a mixture of glycerine and gelatine, 1–2 drops being mounted on the palynological slide. The visualisation of the palynomophs was accomplished by using a Leica DM1000 microscope, using the amplification of X100, X400.

The method used for palaeoclimatic estimations is the „Coexistence Approach" (CA), described by Mosbrugger and Utescher (1997). This method was frequently used for reconstruction of the European Tertiary paleoclimate. The coexistence approach applied for all taxa establishes the relative life conditions (NLR - Nearest Living Relative) and climate of tolerance (maximum and minim values) for the fossil flora, respective variations of the climatic parameters (Mean annual temperature – MAT; Mean annual precipitation – MAP; Mean temperature of the warmest month – WMMT and Mean temperature of the coldest month – CMMT) a.o. The coexistence intervals used for this study have been taken from Gebka et al. (1999); Olivares et al. (2004); Kou et al. (2006); Akkiraz et al. (2006, 2008).

PALAEOFLORISTIC DATA

The palynological assemblage analyzed in this paper derived from 7 samples taken from Şupanu Formation (Asău and Lăloaia-Galeon cuvettes). Macroflora was collected from outcrop A, in the western part of the Lăloaia-Galeon cuvette. The identified palynoflora is presented in Table 1.

Autochthonous phytoplacton consists of *Spiniferites ramosus, Systematophora placacantha, Homotryblium* sp., species that indicate a lagoonal or inner neritic environment. Species as *Spirogyra* identified in P 13

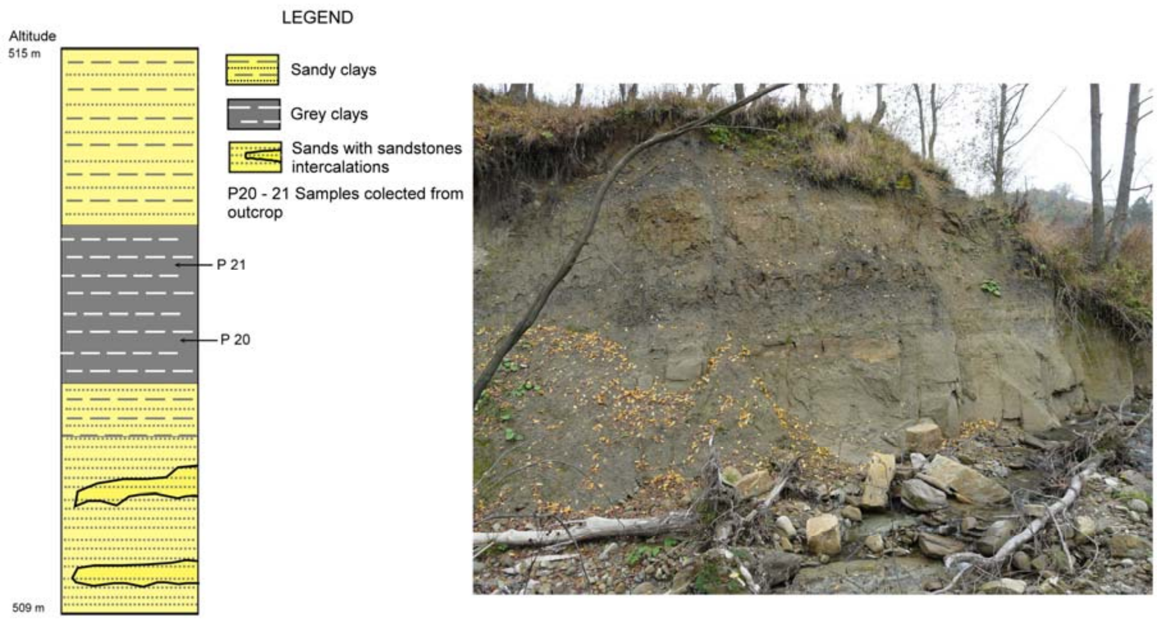

Fig. 3 Lithological column in Şupanu Formation identified in the middle part of the Asău cuvette (Outcrop B, Fig. 1).

(Lăloaia-Galeon cuvette) with a low frequency come from green algae (**ZYGNEMATACEAE** family*)* and indicate a fresh water environment (swamp or lakes). A higher percentage of *Spyrogira* has been cited from the Bârnova-Muntele Formation (Upper Bessarabian) of the Moldavian Platform by Ţabără (2008). The sedimentation of this formation was accomplished in a sweetening stage of the waters in the Moldo–Galiţian bay.

Among reworked phytoplankton species we have found *Wetzeliella* cf. *symmetrica*, *Deflandrea phosphoritica* and *Cribroperidinium edwardsii.* This last taxon is present in higher percentage in sample P21 (Asău cuvette) and was cited before in „Green Sands" deposits with Albian age from Moesian Platform (Balteş, 1967) and in Pieniny Klippen Belt deposits (Western Carpathians from Slovakia) with lower Cretaceous age (Skupien, 2003).

The ferns are relatively diversified and less frequent and are represented by *Schizaeceae* as *Leiotriletes wolffi wolffi, L. microlepioidites* and species of *Polypodiaceae* as *Laevigatosporites haardti haardti, Polypodiaceoisporites saxonicus, P. minutus* a.o. As in the phytoplankton case, a higher percentage of the reworked species have been observed. In sample P21 (Asău cuvette) the percentage of the reworked species is more than 54%. From the reworked species we have found: *Clavifera triplex* (with highest percentage), *Gleicheniidites* div. sp., *Cyathidites australis, Cicatricosisporites* sp. a.o. (Table 1). Reworked taxa can be easily observed using Thermal Alteration Index (TAI; Pearson, 1984). For the reworked species TAI values between 3 and 3+ (a dark brown colour of exine spores) was detected, as compared with autochthonous species with TAI of 2 (yellow colour of palynomorphs). These reworked species come from the Carpathian Flysch deposits (Cretaceous–Paleogene) which are disposed under the Comăneşti Basin deposits.

Conifers are numerous in this palynological assemblage (Table 1), *Pinaceae* being the main taxa: *Pityosporites minutus, P. labdacus,* and *P. microalatus*. Also, we have noted a higher frequency of genus *Tsuga* (*Zonalapollenites rueterbergensis, Z. verrucatus*), especially in samples from Lăloaia-Galeon cuvette. Subordinately, species as *Picea, Abies, Cedrus* and *Podocarpus* are also present*.*

The **TAXODIACEAE** – **CUPRESSACEAE** pollen presents a low frequency, although these deposits contain coals interlayers. It was identified in samples from both cuvettes, represented by pollen of *Taxodium* (*Inaperturopollenites hiatus*), *Glyptostrobus* (*Inaperturopollenites concedipites*), *Sciadopitys, Cupressus* and (very rarely) *Sequoia*.

Monocotyledonous angiosperms are less diversified, with a higher frequency of pollen derived from aquatic plants such as *Typha* and *Sparganium*, found in samples from Lăloaia-Galeon cuvette. Sporadically, pollen of palm trees (*Monocolpopollenites tranquillus*) and grass (*Graminidites media*) was observed.

Among the dicotyledonous angiosperms, FAGACEAE family with *Fagus* pollen (*Faguspollenites minor*), *Quercus* (*Quercopollenites granulatus, Q. petrea, Tricolporopollenites microhenrici, T. henrici*) and *Castanopsis* (*Tricolporopollenites cingulum pusillus*) dominate. JUGLANDACEAE family includes in particular *Engelhardtia* pollen (*Engelhardtioidites microcoryphaeus*) and scarce pollen of *Juglans, Carya, Pterocarya*. Other dicotyledonous species in the studied assemblage are: *Myrica, Liquidambar, Cyrilla, Tilia, Acer, Alnus, Zelkova, Ulmus, Salix* a.o.

The macroflora collected from outcrop A shows a high degree of conservation; the following species were identified: *Glyptostrobus europaeus, Typha latissima, Taxodium dubium, Salix varians, Byttneriophyllum tiliaefolium, Phragmites oeningensis, ?Castanea* sp., and *Betula* sp..

Table 1. Taxonomic list of the palynomorphs identified in the analysed samples (Şupanu Formation).

	Phytoplankton	P9	P11	P12	P13	P16	P20	P21
	Lingulodinium sp.							x
	Systematophora placacantha (Deflandre & Cookson 1955) Davey et al. 1969	x		x				x
	Palaeocystodinium sp.			x				
	Tytthodiscus sp.				+	x	x	
	Spirogyra sp.				x			
	Homotryblium sp.				x			
	Hystrichokolpoma sp.				x			
	Spiniferites ramosus (Ehrenberg 1838) Mantell 1854							x
	Impagidinium sp.							x
	Indeterminable species			x	x		x	+
reworked	*Wetzeliella* cf. *symmetrica* Weiler 1956		x					
reworked	*Deflandrea phosphoritica* Eisenack 1938		x				x	
reworked	*Cribroperidinium edwardsii* (Deflandre & Cookson 1955) Davey et al. 1969							•
reworked	*Odontochitina* sp.							x
	Pteridophyta							
	Leiotriletes wolffi wolffi Krutzsch 1962				x			
	Leiotriletes wolffi brevis Krutzsch 1962							x
	Leiotriletes microlepioidites Krutzsch 1962						x	x
	Leiotriletes sp.			x				
	Laevigatosporites gracilis Wilson - Webster 1946		x					
	Laevigatosporites *haardti* (Potonié & Ven. 1934) Th. & Pflug, 1953 subsp. *haardti* Krutzsch 1967			x	x			x
	Laevigatosporites haardti haardtioidites Krutzsch 1967					x		
	Laevigatosporites sp.				x		x	
	Polypodiaceoisporites saxonicus Krutzsch 1967		x					
	Polypodiaceoisporites gracillimus Nagy 1963			x	x			
	Polypodiaceoisporites minutus Nagy 1969				x			x
	Trilites cf. multivallatus (Pflug 1953) Krutzsch 1959		x					
	Verrucatosporites cf. *favus* Potonié 1931				x			
	Monoleiotriletes gracilis Krutzsch 1959				x		x	
	Stereisporites sp.					x		x
reworked	*Alisporites* sp.							x
reworked	*Clavifera triplex* (Bolkhovitina 1953) Bolkhovitina 1966							•
reworked	*Cicatricosisporites* sp.						x	+
reworked	*Gleicheniidites bulbosus* Kemp 1970							x
reworked	*Gleicheniidites* sp.	x						+
reworked	*Echinatisporis wiesaënsis* Krutzsch 1963					x	x	
reworked	*Polypodiaceoisporites* sp.					x		x
reworked	*Cyathidites australis* Couper 1953							x
reworked	*Toripuctisporis granuloides* Krutzsch 1959							x
reworked	*Trilobosporites weylandi* Döring 1965							x
reworked	*Leiotriletes* sp.							+
reworked	*Undulatisporites intrarugulatus* De-xin et al. 1988			x				
reworked	*Lycopodiumsporites* sp.							x
reworked	Indeterminable spores	x				x	x	••

Gymnospermatophyta							
Pityosporites sp.	+	+	+	•	+	•	+
Pityosporites minutus (ZAKLINSKAJA 1957) KRUTZSCH 1971				+		x	
Pityosporites labdacus (POTONIE 1931) THOMSON ET PFLUG 1953	x	x	x	x			x
Pityosporites microalatus (POTONIE 1931) THOMSON ET PFLUG 1953	x	+	x	+		x	+
Pityosporites alatus (POTONIE 1931) THOMSON ET PFLUG 1953	x	x	x	x	x	x	x
Pityosporites insignis (NAUMOVA EX BOLCHOVITINA 1953) KRUTZSCH 1971	x					x	
Pinuspollenites miocaenicus NAGY 1985					x		
Piceapollis planoides KRUTZSCH 1971			x				
Piceapollis praemarianus KRUTZSCH 1971		x					
Piceapollis sp.		+	x				
Abiespollenites sp.	x	x					x
Podocarpidites sp.		x					
Cedripites miocaenicus KRUTZSCH 1971		x					
Inaperturopollenites concedipites (WODEHOUSE 1933) KRUTZSCH 1971	x			x	x		
Inaperturopollenites hiatus (POTONIE 1931) THOMSON ET PFLUG 1953	+			x	x	x	x
Inaperturopollenites microforatus KRUTZSCH 1971		x					
Inaperturopollenites sp.		x	x	x		x	+
Sequoiapollenites minor KRUTZSCH 1971						x	x
Cupressacites bockwitzensis KRUTZSCH 1971							x
Sciadopityspollenites serratus (POTONIE ET VEN. 1934) THIERGART 1937						x	
Sciadopityspollenites sp.		x		x			
Zonalapollenites verrucatus KRUTZSCH 1971		+		x			
Zonalapollenites rueterbergensis KRUTZSCH 1971	x	+					x
Zonalapollenites minimus KRUTZSCH 1971		x					
Zonalapollenites spinulosus KRUTZSCH 1971			x				
Zonalapollenites sp.	x	+	x	x			
Ginkgo sp.				x			
Angiospermatophyta. Monocotyledonatae							
Monocolpopollenites tranquillus (POTONIE 1934) THOMSON ET PFLUG 1953	x						
Monocolpopollenites sp.		x		x	x		
Sparganiaceaepollenites polygonalis THIERGART 1937		x		•			
Typha angustifolia LESCHIK 1956		•					
Graminidites media (COOKSON 1947) POTONIÉ 1960		x	x				
Angiospermatophyta. Dicotyledonatae							
Tricolporopollenites cingulum (POTONIE 1931) THOMSON ET PFLUG 1953 subsp. *pusillus* (POTONIE 1934) THOMSON ET PFLUG 1953		x	x	x		x	
Tricolporopollenites microhenrici (POTONIÉ 1930) KRUTZSCH 1960	x	x	+	+			
Tricolporopollenites henrici (POTONIÉ 1931) KRUTZSCH 1960	x		x				
Tricolporopollenites sp.	x		+	+			x
Quercopollenites granulatus NAGY 1969		+					
Quercopollenites robur NAGY 1969				x			
Quercopollenites petrea NAGY 1969				x	x		
Quercopollenites sp.		x	x	x			
Faguspollenites minor NAGY 1969			x	x			
Faguspollenites sp.				x			

Tricolpopollenites liblarensis (THOMSON 1950) THOMSON ET PFLUG 1953 subsp. *liblarensis*	x	x		+	+	x	
Tricolpopollenites liblarensis (THOMSON 1950) THOMSON ET PFLUG 1953 subsp. *fallax* (POTONIÉ 1934) THOMSON ET PFLUG 1953			x				
Myricipites bituitus (POTONIÉ 1931) NAGY 1969	x	x	x				
Myricipites sp.	x	x	x	x			x
Juglanspollenites sp.	x						
Pterocaryapollenites stellatus (POTONIÉ 1931) THIERGART 1937	x						
Porocolpopollenites vestibulum (POTONIE 1931) THOMSON ET PFLUG 1953		x					
Liquidambarpollenites stigmosus (POTONIÉ 1931) RAATZ 1937 EX POTONIE 1960		x					
Liquidambarpollenites sp.				x		x	
Engelhardtioidites microcoryphaeus (POTONIE 1931) THOMSON ET THIERGART EX POTONIE 1960		+	x	+	x	x	
Momipites punctatus (POTONIÉ 1931) NAGY 1969				x			
Cyrillaceaepollenites exactus (POTONIÉ 1931) POTONIÉ 1960		x	x				
Cyrillaceaepollenites megaexactus (POTONIÉ 1931) POTONIÉ 1960				x			
Intratriporopollenites instructus (POTONIE 1931) THOMSON ET PFLUG 1953		x		x			
Aceripollenites rotundus NAGY 1969		x					
Aceripollenites sp.					x		
Platycaryapollenites sp.		x					
Caryapollenites simplex (POTONIÉ 1931) KRUTZSCH 1960			x	+	x		
Alnipollenites verus (POTONIÉ 1931) POTONIÉ 1934			x				
Zelkovaepollenites potoniéi NAGY 1969			x				
Ulmipollenites undulosus WOLFF 1934				x			
Chenopodipollis multiplex (WEYLAND ET PFLUG 1957) KRUTZSCH 1966			x				
Magnolipollis sp.			x				
Eucommiapollis eucommi (PLANDEROVA 1990) PETRESCU 1999				x			x
Salixipollenites helveticus NAGY 1969				x			

Frequency: x – very scarce (1–2 grains); + - scarce (3-9 grains); • – frequent (10-20 grains); •• - very frequent (> 21 grains).

PALAEOCLIMATICAL AND PALAEOENVIRONMENTAL RECONSTRUCTION

Palaeoenvironmental and palaeoclimatical interpretation was built based on the identified palynological assemblage and macrofloristic taxa. Based on these data, one can outline the following paleobiocenosis (Fig. 4):

1. Subtropical swamp forest, where the main identified taxa as palynomorphs and foliar impressions was *Glyptostrobus* and *Taxodium.* In outcrop A (western flank of anticline), clay intercalations with numerous remains of *Glyptostrobus* were intercepted. In addition to these taxa, the swamp included various species of ferns and another representative of swamp forest such as *Byttneriophyllum tiliaefolium*.

2. Lake vegetation was dominated by *Typha*, *Phragmites* and *Sparganium*. These taxa have been identified both as pollen and foliar impressions only in the outcrop of Lăloaia-Galeon cuvette.

3. Riparian assemblage of a lowland developed behind a coastal vegetation (*Engelhardtia, Salix, Myrica, Cyrilla, Tilia, Ulmus, Zelkova, Liquidambar, Alnus*) and mixed mesophitic forest represented by various species of *Quercus, Fagus, Carya, Juglans* a.o.

4. Middle- and high-altitude forest, dominated by taxa such as *Tsuga, Abies, Picea* and *Pinus.* The most frequent taxa in this palynological assemblage are *Pinus* and *Tsuga.*

5. "Open area" vegetation is poorly represented in the palaeofloristic assemblage. We noted the presence in very low frequencies of *Chenopodiaceae* and *Gramineae* pollen.

By applying the „Coexistence approach” method to the analyzed palynological assemblage (34 taxa) we have calculated the following palaeoclimatical parameters (Fig. 5):

- MAT: 15.3–16.6 °C
- MAP: 1300–1355 mm/yr
- CMMT: -0.3 –7 °C
- WMMT: 21.6–28.5 °C

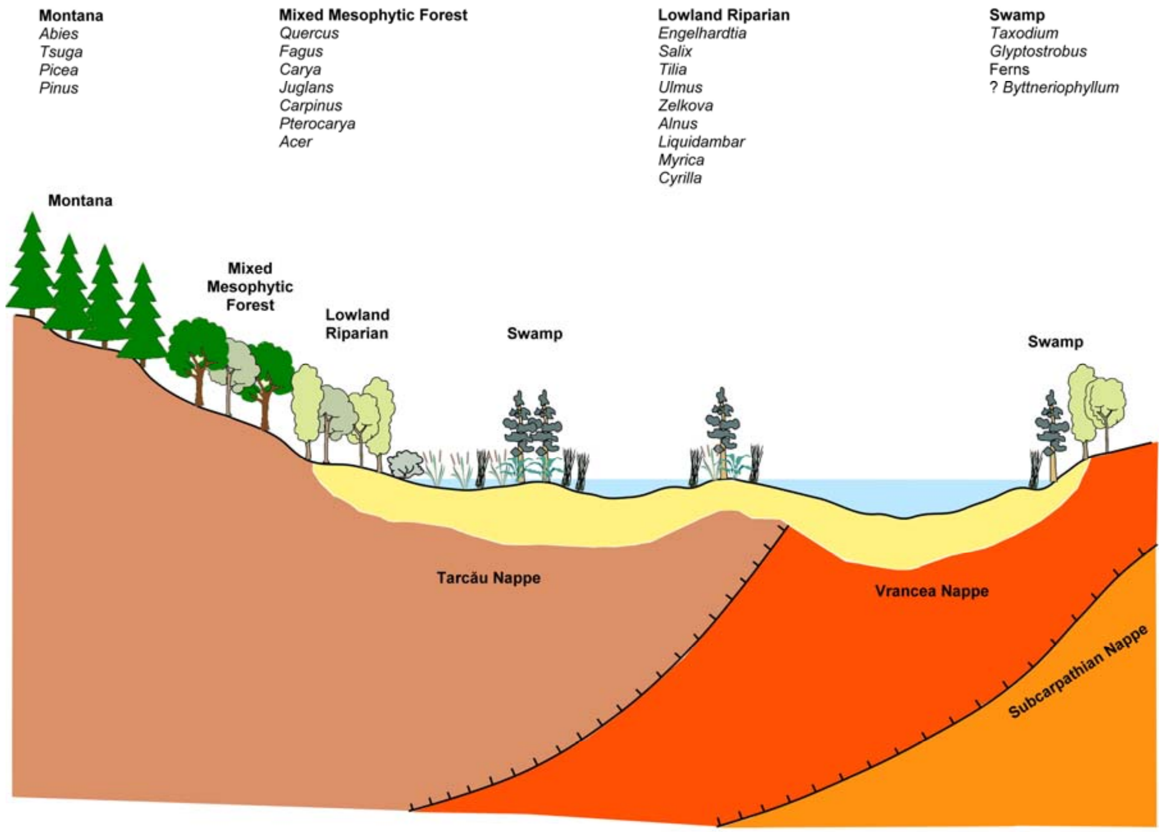

Fig. 4 Paleoenvironmental reconstruction during the sedimentation of Şupanu Formation (Comăneşti Basin).

A similar study on Bessarabian–Kersonian palynological assemblages from the Moldavian Platform was accomplished by Ţabără (2008). When comparing the results on palaeoclimatical values, one can summarize the following:

- regarding MAT parameter, one can observe approximatively equal values for the Bessarabian deposits of the Moldavian Platform (15.7–16.6° C) as compared to the value calculated for Comăneşti area. During the Kersonian, the values of MAT from Moldavian Platform were slightly lower, amounting to approx. 15 °C.

- MAP values calculated for Comăneşti area are similar with those for Bessarabian microfloras from Moldavian Platform.

- CMMT values for Bessarabian–Kersonian deposits of Moldavian Platform were relatively higher (5–9.6 °C) as compared with values calculated for Comăneşti Basin. We believe that this is related to the geographical position of the latter during the Sarmatian, *i.e.* on the edge of the Eastern Carphatians. Also, lower values as compared with those for the Sarmatian from Moldavian Platform were recorded for the WMMT.

PALYNOFACIES DESCRIPTION

Palynofacies analysis involves identifying the palynomorphs, phytoclasts and amorphous organic matter under the microscope and estimating the proportion of total organic matter (Combaz, 1964; 1980).

Several authors, such as Combaz (1964), Batten (1983), Steffen and Gorin (1993), Tyson (1995), Bombardiere and Gorin (2000), Ercegovac and Kostić (2006) have studied the organic matter in transmitted light (mounted on palynological slides). In this paper we used the classification according to Bombardiere and Gorin (2000).

Two groups of organic particles were distinguished:

1. Continental organic matter including opaque phytoclasts (black coal remains), brown and yellow phytoclasts (from the degradation of continental organic matter), woody tissues, cuticle and terrestrial palynomorphs (spores and pollen). Here we included amorphous organic matter (AOM) derived from the degradation of terrestrial constituents. According to Bombardiere and Gorin (2000), that type of AOM shows no fluorescence.

2. Marine organic matter is composed of marine phytoplankton, tests of foraminifera and Amorphous Organic Matter (AOM) derived from the alteration of marine constituents. This type of AOM fluorescencens, and it is considered in thermally immature sediments as having an algal-bacterial origin (Staplin, 1969, Tyson, 1987).

Organic matter studied in transmitted and fluorescent light allowed the separation of the following groups:

a. Phytoclasts – they are the main component in the analized samples, with a frequency between 80 – 98 %; they don’t fluorescence (Plate V, Fig. 3, 4).

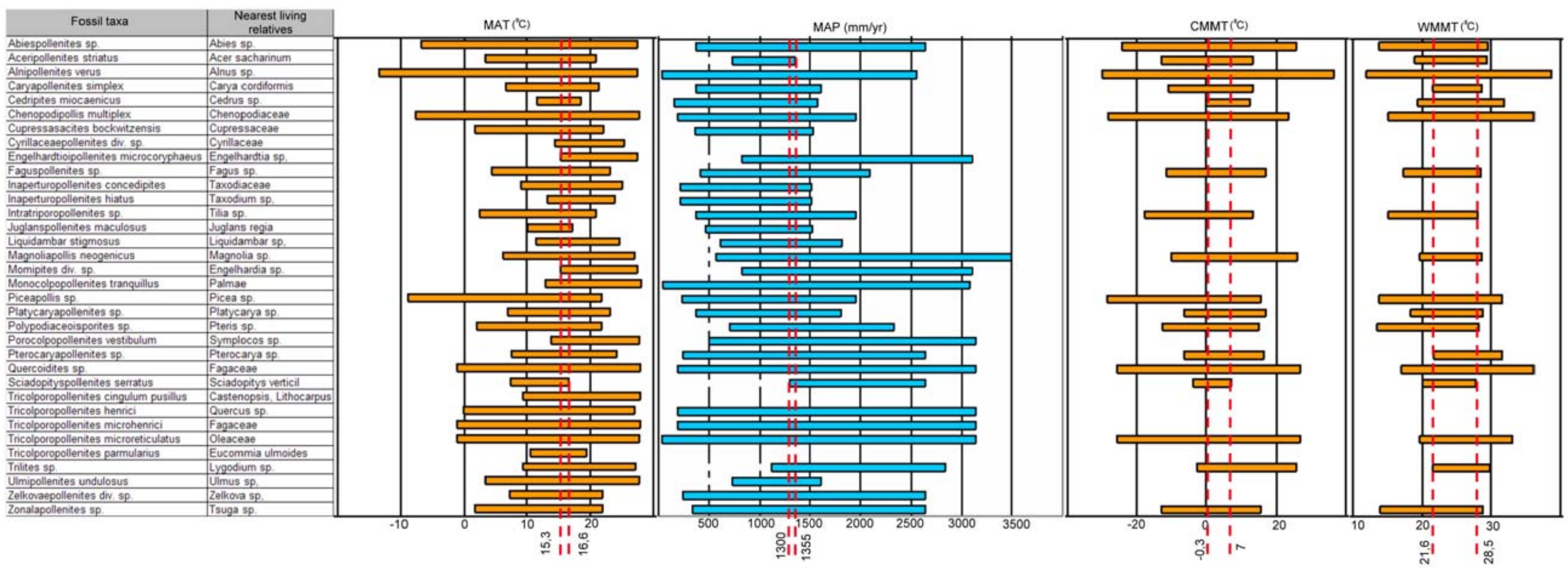

Fig. 5 Palaeoclimatic values estimated by using the „Coexistence approach" method for the microflora identified in samples from Şupanu Formation (Bessarabian–Kersonian).

Among these, the most numerous are black fragments (coal) and brown phytoclasts with no visible structure, which can be included into the inertinites group of macerals (Ercegovac and Kostić, 2006). These have a continental origin (fragments of wood tissue) and a greater resistance to transport on longer distances as compared with other organic compounds present in kerogen.

In some samples (P12, P16) black fragments are abundant (Plate V, Fig. 1), being present as agglomerations of small particles (approx. 10–15 μm). Probably, the small dimension of the particle is due to relatively high hydrodynamic regime in the sedimentary basin. These fragments are dominant in freshwater swamp, lagoons or oxic marine basins (Tyson, 1995; Ercegovac & Kostić, 2006).

b. Woody tissues - include fragments whose structures are observable under a microscope. They generally have a brown–dark brown colour and a fibrous parallel structure (Plate V, Fig. 2). The frequency in the samples analyzed is approximately of 3 to 5 %. This category of phytoclasts is specific for swamp facies and other sediments rich in continental organic matter (Ercegovac and Kostić, 2006). These woody tissues don't fluoresce. Cuticles (leaf-epidermal tissue) have a very low frequency in the material under study.

c. Continental palynomorphs - include species of spores and pollen identified and presented in Table 1. Their preservation status is generally good, allowing observation of all morphological aspects. The colour (exina) is generally yellow corresponding to a Thermal Alteration Index (TAI) of 2+ (Pearson, 1984). Palynomorphs colour in fluorescence light is yellow-green (Plate VI, Figs. 2, 4), which corresponds to a vitrinite reflectance (VR_0) between 0.4 and 0.5 % (Pearson, 1984; Blažeković Smojić et al., 2009). Based on the TAI and vitrinite reflectance, it can be concluded that organic matter contained in the investigated samples shows an early maturing phase.

In sample P21 (Asău cuvette) we have identified a high frequency of reworked spores (54 %), easily recognized based on their colour. The TAI is 3 to 3+ (according to Pearson, 1984), and the colour under the fluorescent light is brown–orange (Plate VI, Fig. 5).

d. Amorphous organic matter (AOM) - is present in small amounts in the analyzed samples (2 to 3 %), as grains (Plate V, Fig. 5) in combination with various phytoclasts (black and brown remains). This AOM does not show fluorescence (Plate V, Fig. 6), leading us to the assumption that it would have a continental origin, being derived from degradation processes of plant remains from the continent.

Occasionally, some AOM particles originating from the degradation of phytoclancton have a more intense fluorescence colour (bright yellow) (P13, Lăloaia-Galeon cuvette; Plate V, Fig. 8).

e. Phytoplankton - consists of a limited number of species with low frequency (Table 1). These indicate a lagoon or inner neritic environment; some species (*Spirogyra*) come from a freshwater biotope (lakes, swamps).

Among the reworked species of phytoplankton we can mention *Wetzeliella* cf. *symmetrica, Deflandrea phosphoritica* and many taxa of *Cribroperidinium edwardsii* in P21 (Table 1). This last taxon shows black colour in transmitted light and dark-brown colour in fluorescent light (Plate VI, Figs. 7, 8).

CONCLUSIONS

The identified (macro- and micro-) palaeoflora points to the presence of a swamp vegetation (*Taxodium, Glyptostrobus* a.o.), lowland riparian vegetation (*Engelhardtia, Salix, Alnus* a.o.), a mixed mesophytic forest and a higher altitude vegetation. Palaeofloristical indices for open space areas are poorly-represented in the identified assemblage.

Palaeoclimatic parameters estimated by applying the "Coexistence approach" method to the analyzed microflora indicate MAT values between 15.3–16.6 ° C, MAP values from 1300 to 1355 mm/year, CMMT of -0.3–7 ° C and WMMT from 21.6 to 28.5 ° C, corresponding to a warm-temperate climate.

Organic matter extracted from the analyzed samples is mostly coming from the continent (black phytoclasts, brown and yellow residues, woody tissues, spores and pollen). We believe that the AOM, present in small quantities in the analyzed samples (approx. 2-3 %), has a continental origin because it almost entirely shows no fluorescence.

Also, reworked specimens of spores and phytoplankton were frequenly observed (up to 64 % of the total identified species in sample P21).

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PLATES

Plate I

1. *Impagidinium* sp.
2. *Systematophora placacantha* (Deflandre et Cookson 1955) Davey et al. 1969
3. *Spirogyra* sp.
4. *Palaeocystodinium* sp.
5. *Homotryblium* sp.
6. *Tytthodiscus* sp.
7. *Spiniferites ramosus* (Ehrenberg 1838) Mantell 1854

8, 9, 10. *Cribroperidinium edwardsii* (Cookson et Eisenack 1958) Davey 1969 (reworked)

11. *Polypodiaceoisporites saxonicus* Krutzsch 1967
12. *Polypodiaceoisporites gracillimus* Nagy 1963
13. *Leiotriletes wolffi wolffi* Krutzsch 1962
14. *Leiotriletes wolffi brevis* Krutzsch 1962

Plate II

1. *Laevigatosporites haardti* (POTONIÉ ET VEN. 1934) TH. ET PFLUG, 1953 subsp. *haardti* KRUTZSCH 1967
2, 3, 4. *Clavifera triplex* (BOLKHOVITINA 1953) BOLKHOVITINA 1966 (reworked)
5. *Gleicheniidites bulbosus* KEMP 1970 (reworked)
6, 7, 8. *Gleicheniidites* sp. (reworked)
9. *Lycopodiumsporites* sp. (reworked)
10. *Cyathidites australis* COUPER 1953 (reworked)
11. *Cicatricosisporites* sp. (reworked)
12. *Trilobosporites weylandi* DÖRING 1965 (reworked)
13. *Inaperturopollenites hiatus* (POTONIE 1931) THOMSON ET PFLUG 1953
14. *Sequoiapollenites minor* KRUTZSCH 1971
15. *Pityosporites insignis* (NAUMOVA EX BOLCHOVITINA 1953) KRUTZSCH 1971
16. *Pityosporites alatus* (POTONIE 1931) THOMSON ET PFLUG 1953
17. *Pinuspollenites miocaenicus* NAGY 1985
18. *Pityosporites minutus* (ZAKLINSKAJA 1957) KRUTZSCH 1971
19. *Sciadopityspollenites serratus* (POTONIE ET VEN. 1934) THIERGART 1937
20. *Cedripites miocaenicus* KRUTZSCH 1971

Plate III

1, 2. *Zonalapollenites verrucatus* KRUTZSCH 1971
3, 4. *Zonalapollenites rueterbergensis* KRUTZSCH 1971
5. *Piceapollis planoides* KRUTZSCH 1971
6. *Zonalapollenites spinulosus* KRUTZSCH 1971

Plate IV

1, 2. *Typha angustifolia* LESCHIK 1956
3. *Graminidites media* (COOKSON 1947) POTONIÉ 1960
4. *Tricolporopollenites microhenrici* (POTONIÉ 1930) KRUTZSCH 1960
5. *Tricolporopollenites henrici* (POTONIÉ 1931) KRUTZSCH 1960
6. *Engelhardtioidites microcoryphaeus* (POTONIÉ 1931) THOMSON ET THIERGART EX POTONIÉ 1960
7. *Tricolporopollenites cingulum* (POTONIÉ 1931) THOMSON ET PFLUG 1953 subsp. *pusillus* (POTONIÉ 1934) THOMSON ET PFLUG 1953
8. *Liquidambarpollenites stigmosus* (POTONIE 1931) RAATZ 1937 EX POTONIE 1960
9. *Quercopollenites granulatus* NAGY 1969
10. *Myricipites bituitus* (POTONIE 1931) NAGY 1969
11. *Aceripollenites rotundus* NAGY 1969
12. *Intratriporopollenites instructus* (POTONIE 1931) THOMSON ET PFLUG 1953
13. *Caryapollenites simplex* (POTONIE 1931) KRUTZSCH 1960
14. *Cyrillaceaepollenites megaexactus* (POTONIE 1931) POTONIE 1960
15. *Cyrillaceaepollenites exactus* (POTONIE 1931) POTONIE 1960
16. *Faguspollenites minor* NAGY 1969
17. *Zelkovaepollenites potoniéi* NAGY 1969
18. *Alnipollenites verus* (POTONIE 1931) POTONIE 1934
19. *Momipites punctatus* (POTONIE 1931) NAGY 1969

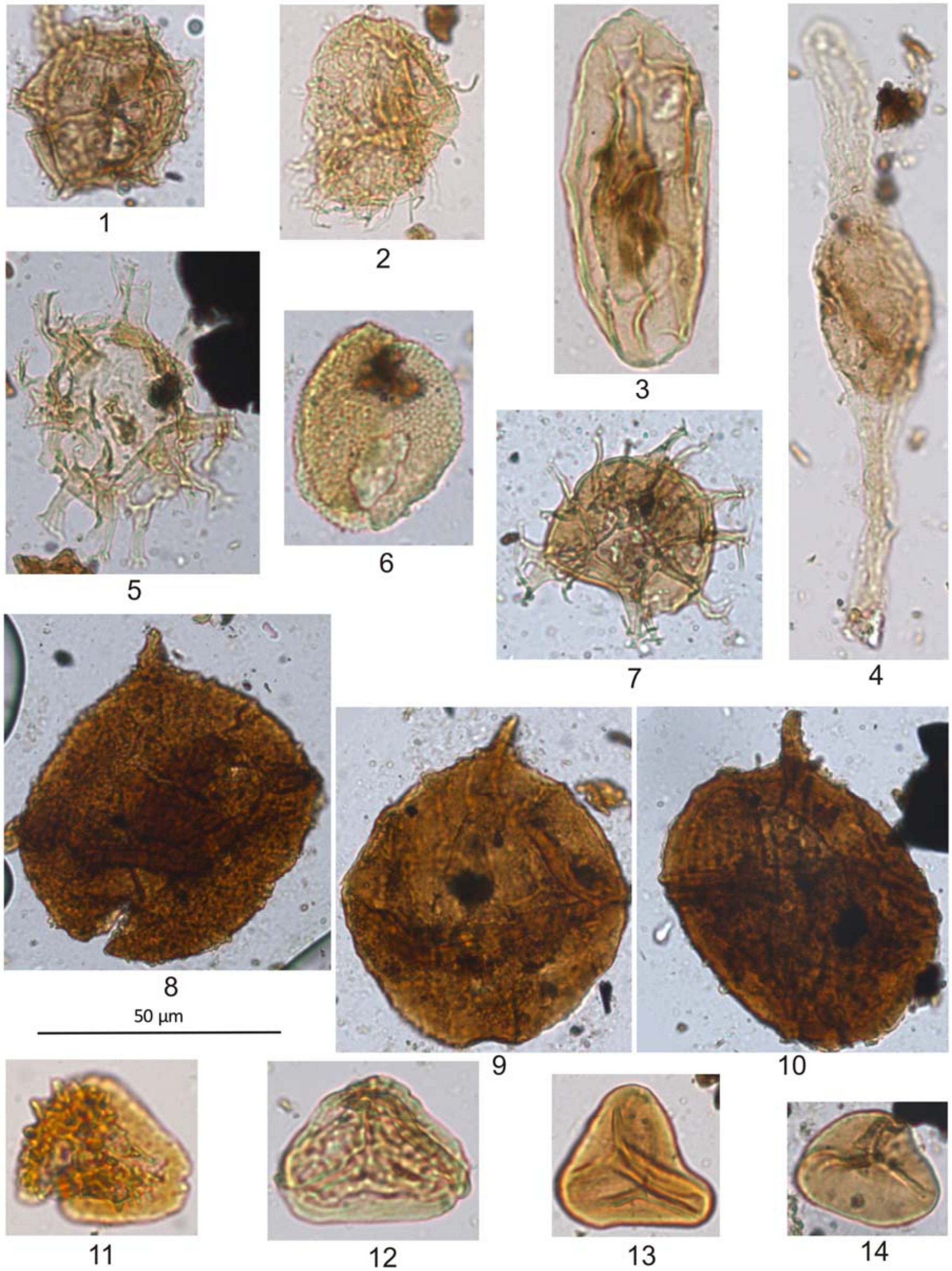
Plate V

1. Agglomeration of phytoclasts (mainly black coals) in P12, indicating swamp, lagoon area and oxic marine basin environments (transmitted white light).
2. Woody tissue with fibrous parallel structure (P12, Lăloaia-Galeon cuvette). (transmitted white light).
3. Typical palynofacies of Şupanu Formation, including phytoclasts (PHY) and palynomorphs (PAL) (transmitted white light).
4. *Idem*, incident blue light (fluorescence).
5. Granular AOM mixed with small fragments of phytoclasts. AOM is non-fluorescent (P11, Lăloaia-Galeon cuvette) (transmitted white light).
6. *Idem*, incident blue light (fluorescence).
7. AOM considered to result from the degradation of phytoplankton (marine organic matter). This AOM presents fluorescence (P13, Lăloaia-Galeon cuvette).
8. *Idem*, incident blue light (fluorescence).

Plate VI

1. Spore identified in P9, Lăloaia-Galeon cuvette. TAI of exina is 2+. (transmitted white light)
2. *Idem*, incident blue light (fluorescence).
3. Polen of *Pinus* (P20, Asău cuvette). TAI is 2+. (transmitted white light)
4. *Idem*, incident blue light (fluorescence).
5. Reworked spore of *Clavifera triplex* (P21, Asău cuvette).
6. *Idem*, incident blue light (fluorescence).
7. *Cribroperidinium edwardsii* reworked from Cretaceous (P21, Asău cuvette). Note almost complete absence of fluorescence due to higher age of the specimen as compared to the autochthonous microflora.
8. *Idem*, incident blue light (fluorescence).

PLATE I



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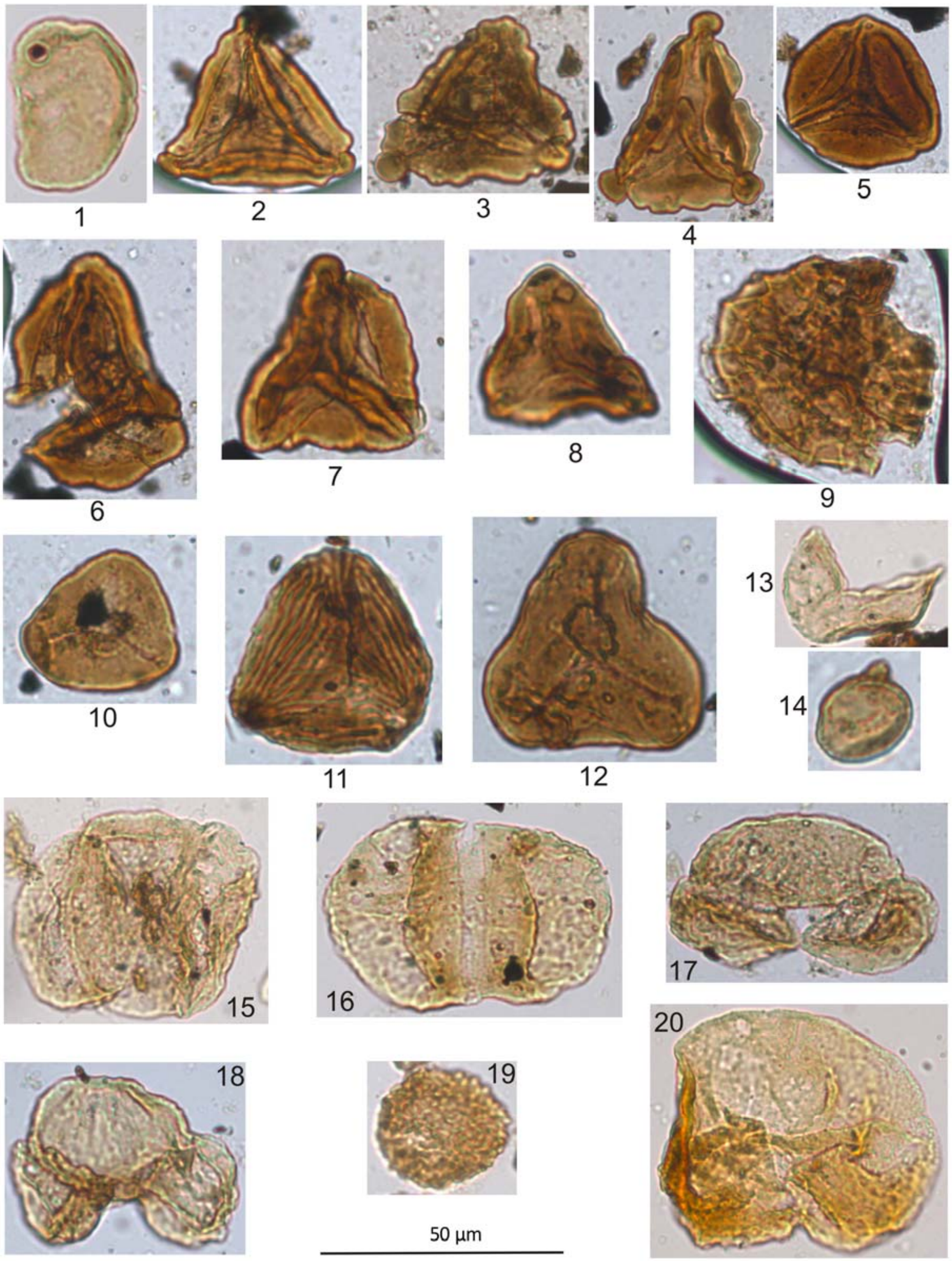

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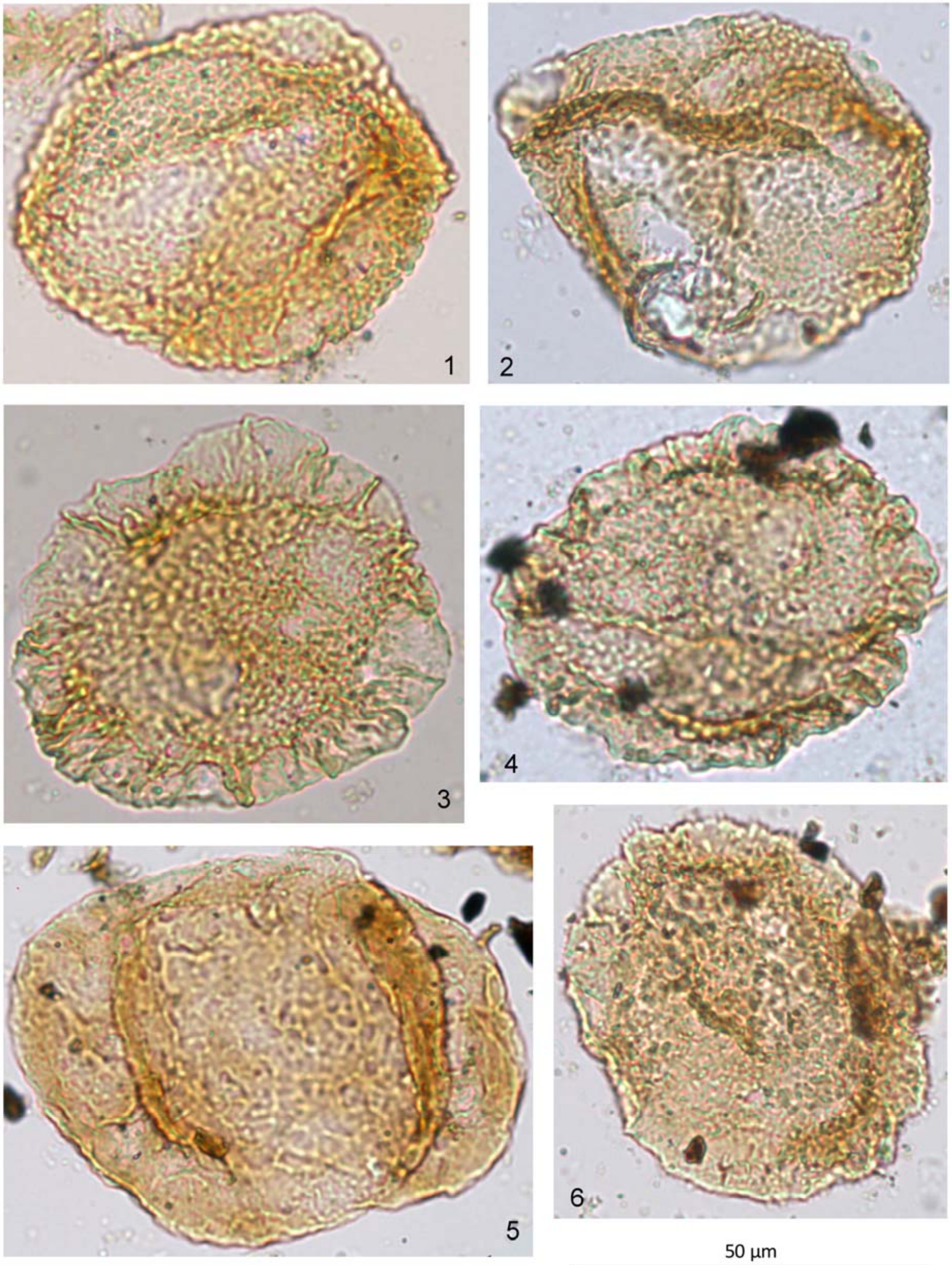

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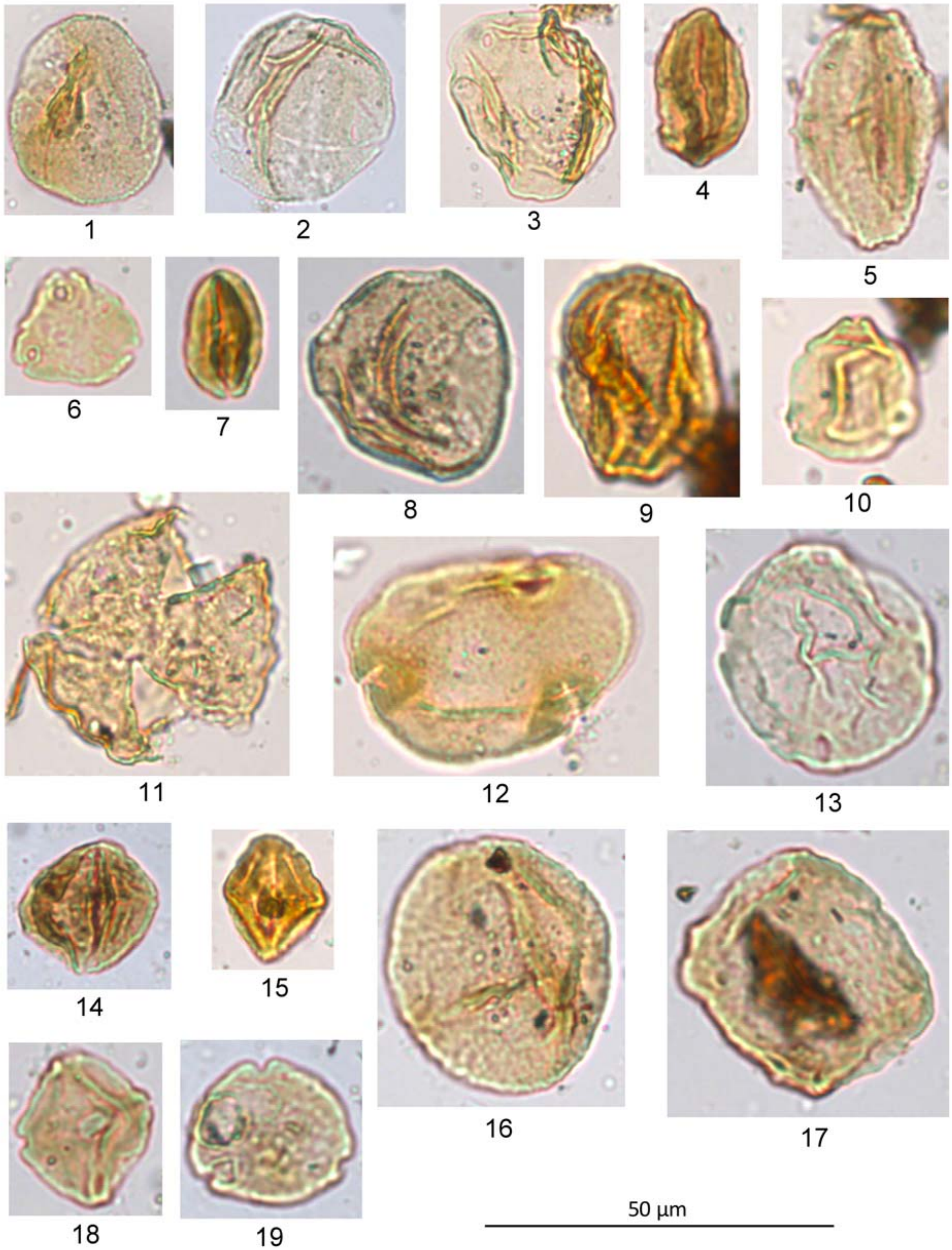

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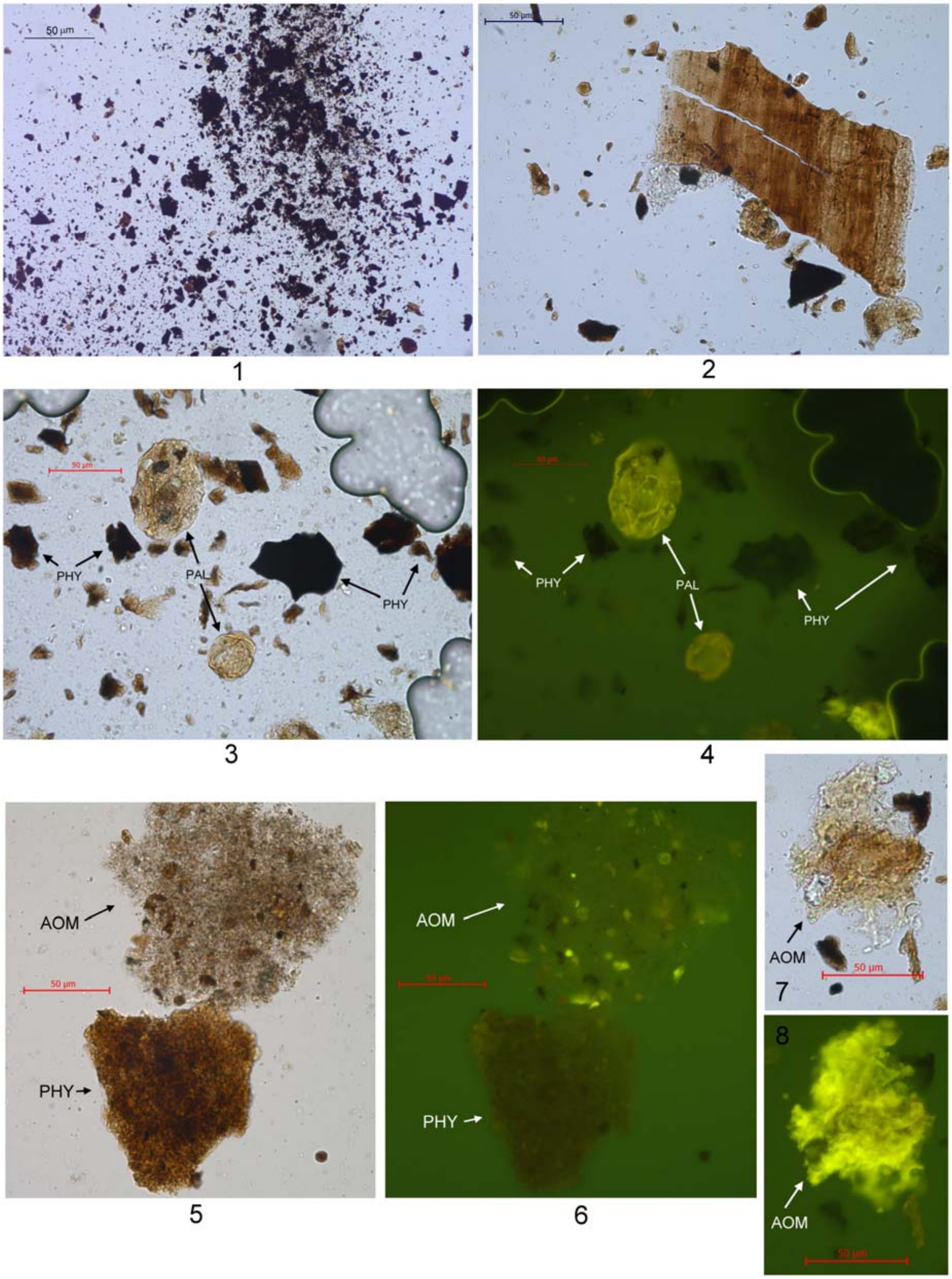
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PLATE VI